Journal

WATER POLLUTION CONTROL FEDERATION

Special Features

Water Pollution Status—Hollis

Anaerobic Digestion—McCarty and McKinney

Vinyl Wastes—Pahren and Bloodgood

Algae in Waste Treatment—Bartsch

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Volume 33 March 1961 Number 3

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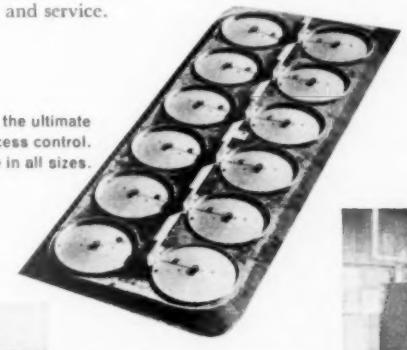

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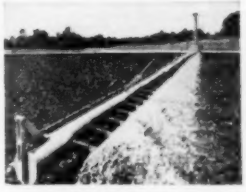

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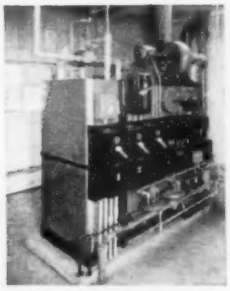

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SUBSCRIPTION RATES: Members of local associations affiliated with the Federation, $8.00 per calendar year. All others, U. S. and Canada: $10.00; other countries, $11.50. (Foreign subscriptions must be accompanied by International Money Order.) Single copies: United States: $1.25 each; foreign, $1.50 each.

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REFERENCE SERVICE: JOURNAL of the WATER POLLUTION CONTROL FEDERATION is indexed regularly by *Industrial Arts Index* and *Engineering Index*. Microfilm copies of this JOURNAL may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

Library of Congress Catalog Card Number: 42–19992.

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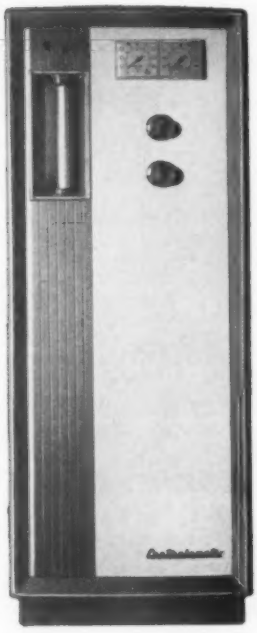

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Association *	*Date*	*Place*
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New Jersey	Mar. 15–17	Traymore Hotel, Atlantic City
Louisiana	Mar. 15–17	Louisiana State University, Baton Rouge
Arkansas	Mar. 19–22	Marion Hotel, Little Rock
West Virginia	Apr. 6–7	West Virginian Hotel, Bluefield
Montana	Apr. 6–8	Placer Hotel, Helena
Kansas	Apr. 12–14	Baker Hotel, Hutchinson
Arizona	Apr. 20–22	San Marcus Hotel, Chandler
California	Apr. 26–29	Hotel Miramar, Santa Monica
Virginia	May 9	Hotel Chamberlain, Old Point Comfort
Maryland-Delaware	May 22–24	Commander Hotel, Ocean City, Md.
Michigan	May 31–June 2	Michigan State University, East Lansing
Alabama	June 5–7	University of Alabama, Tuscaloosa
New England	June 7–8	Snow Inn, Harwichport, Mass.
Central States	June 7–9	Leland Hotel, Springfield, Ill.
Iowa	June 7–9	The New Inn, Okoboji
Ohio	June 14–16	Statler Hotel, Cleveland
ISP (England)	June 19–23	Brighton, England
Pennsylvania	Aug. 9–11	Pennsylvania State University, State College
Kentucky-Tennessee	Sept. 11–13	Brown Hotel, Louisville, Ky.

* See preceding left-hand page for full name.

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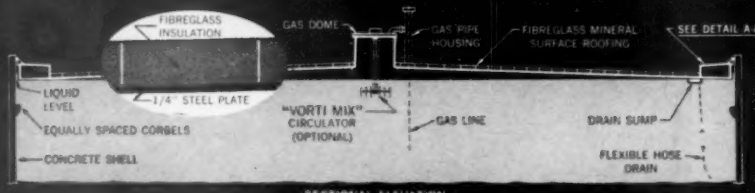

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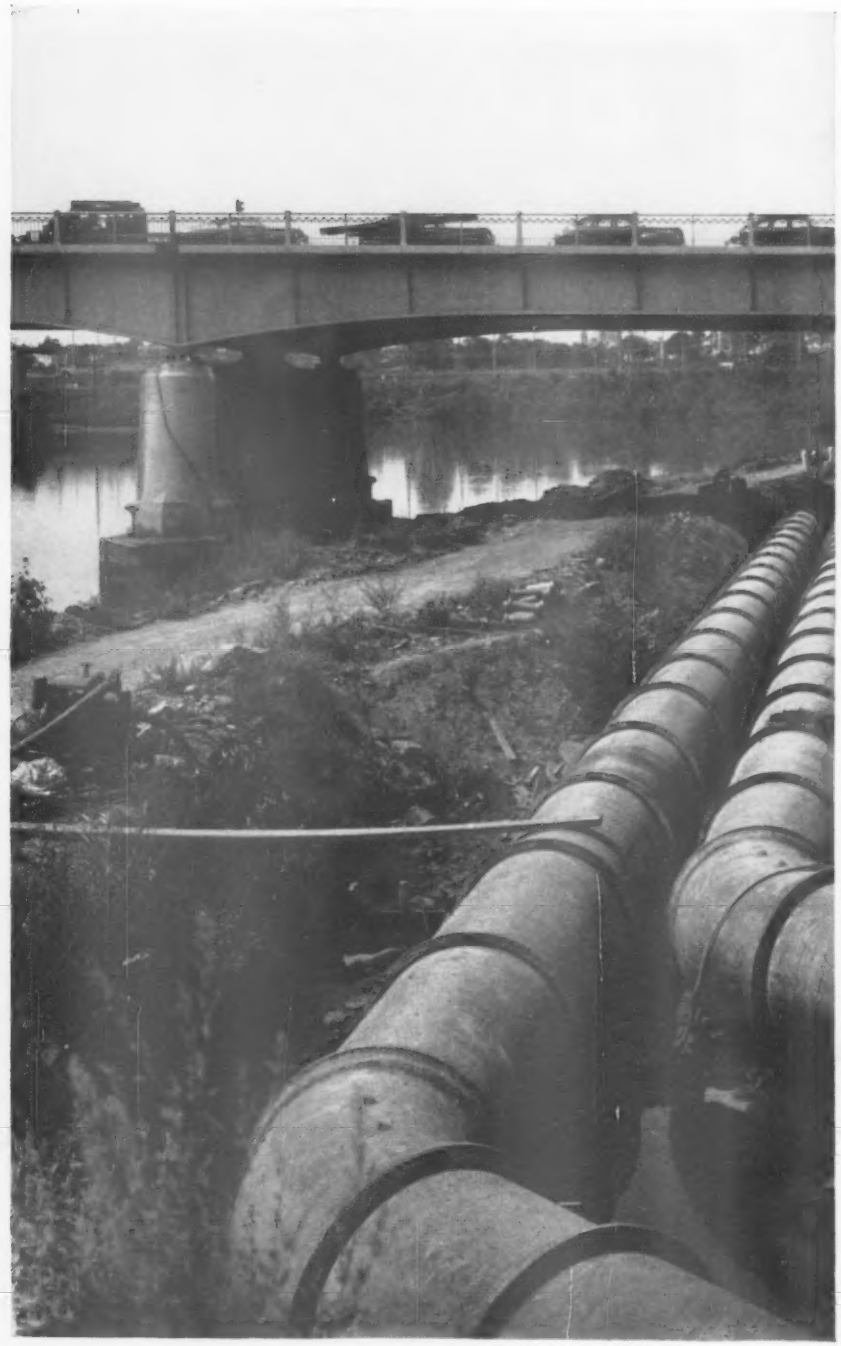

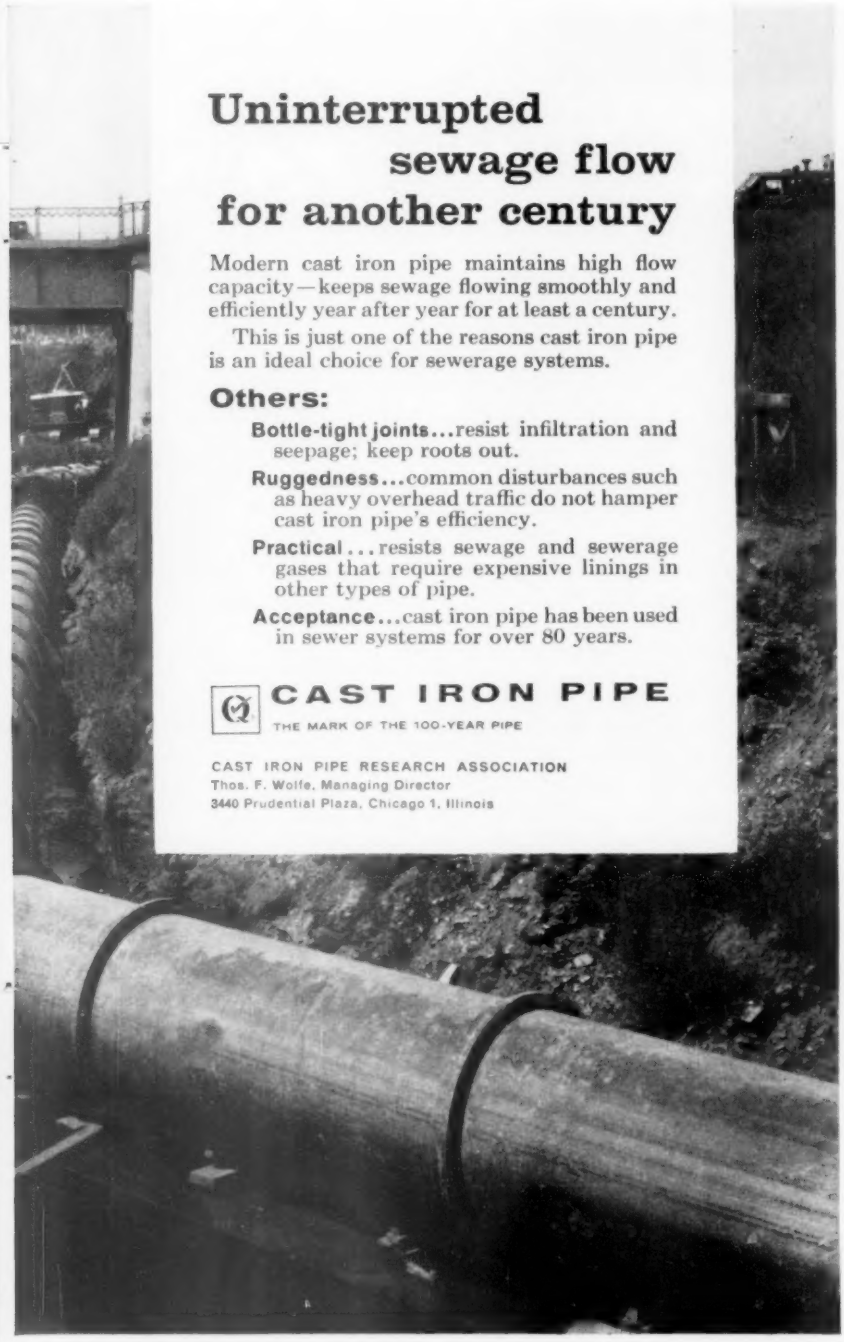

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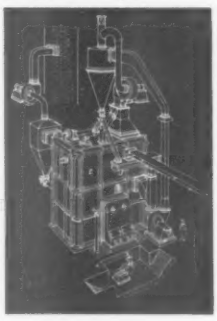
Heart of the C-E 2-in-1 disposal system is the C-E Traveling Grate Incinerator Stoker. Using "continuous processing" the C-E Incinerator Stoker requires only minimum attention and maintenance. Refuse (alone, or mixed with dried sludge) is fed into the self-sealing, non-clogging hopper. It is reduced to a sterile ash, free from clinkers and automatically discharged to the ash pit. This ash is suitable for use as a sanitary land fill.

Heat from the burning waste is used to dry sludge in the C-E Raymond Flash Dryer. This service-proved equipment provides high temperature deodorization and efficient fly ash collection. The dried sludge can then be incinerated to provide heat for further sludge drying, or can be used as a soil conditioner — in parks or recreation areas, or for sale to gardeners.

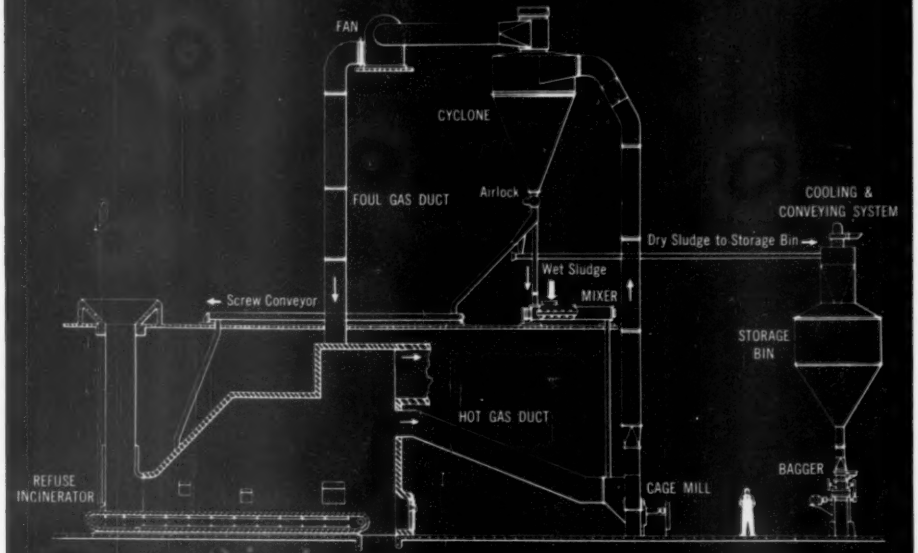


FOR SLUDGE DISPOSAL ALONE, the C-E Raymond Flash Drying and Incinerator System permits both **drying and incineration** of sewage sludge—separately or together—in any proportion. Where combined sewage and refuse disposal is not feasible, this system provides maximum efficiency in processing filter cake.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;

# of waste disposal { 1/2 refuse . . . / 1/2 sewage sludge

land . . . labor . . . fuel . . . capital investment



C-E 2-in-1 REFUSE AND SEWAGE DISPOSAL SYSTEM

This system combines over 50 years' experience in burning every kind of marginal and waste fuel with a drying system that today processes more filter cake than all other systems combined. The entire operation is automatic; efficient, quick and clean. Capacity per dollar of plant investment is increased. Manpower requirements are minimal. The system is capable of burning all types of combustible refuse in quantities ranging upward from 50 tons per 24-hour day.

COMBUSTION C-E ENGINEERING

General Offices: Windsor, Conn. • New York Offices: 200 Madison Ave., New York 16
Raymond Division: 427 West Randolph St., Chicago 6, Ill. • Western Office: 615 So. Flower St., Los Angeles 17, Cal.
Canada: Combustion Engineering-Superheater Ltd.

C-302A

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

FOR SIMPLICITY, EFFICIENCY, ECONOMY...

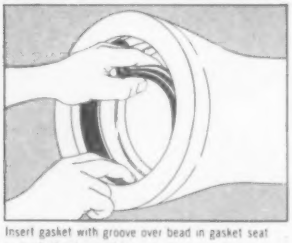
Use Tyton Joint® pipe. It's so quickly, easily installed even inexperienced crews learn to lay it in minutes. No bell holes. No nuts or bolts to tighten. No weather worries, either. You can lay it in rain or wet trench if need be.
Like all the facts about Tyton Joint pipe—the pipe that cuts cost, saves so much time in the trench? Write or call today.

U. S. PIPE AND FOUNDRY COMPANY
General Office, Birmingham 2, Ala.

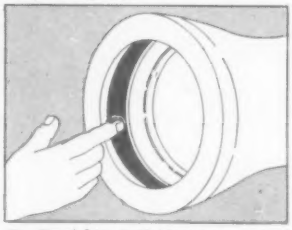
A wholly integrated producer from mines and blast furnaces to finished pipe.

TYTON®

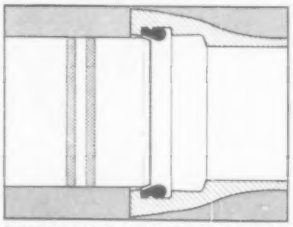
ONLY FOUR SIMPLE ACTIONS



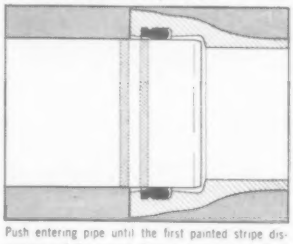
Insert gasket with groove over bead in gasket seat a simple hand operation.



Wipe film of Tyton Joint® lubricant over inside of gasket. Your receiving pipe is ready.



Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.



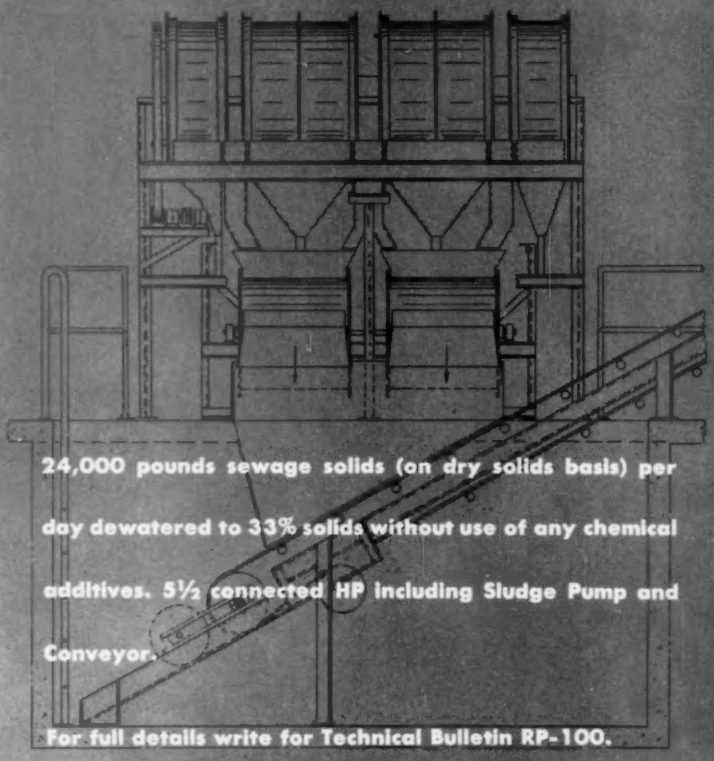
Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . . bottle-tight, permanently! The job's done . . . fast, efficiently, economically. Could anything be simpler?

U.S. cast iron PIPE

FOR WATER, SEWERAGE AND INDUSTRIAL SERVICE

CAST IRON ®

NICHOLS "ROTO-PLUG"* SLUDGE CONCENTRATOR



24,000 pounds sewage solids (on dry solids basis) per day dewatered to 33% solids without use of any chemical additives. 5½ connected HP including Sludge Pump and Conveyor.

For full details write for Technical Bulletin RP-100.

*Equipment Development Corp.

NICHOLS Engineering & Research Corp.
80 Pine Street, New York 5, New York
3513 N. Harvey Street, Indianapolis 18, Ind. • 1336 North Carolan Ave., Burlingame, Calif.

SAN FRANCISCO INTERNATIONAL AIRPORT

Flotation system for oil wastes disposal at United Air Lines maintenance base consists of Eimco-Process Type B Clarifier and Type B Flotator, steel scum tank, rubber-lined storage tank and auxiliaries. Kennedy Engineers, San Francisco, California, Consultants.

Economical Treatment of Miscellaneous Waste Waters . . . with Eimco-Process Equipment

Economical and efficient mechanism designs for a wide range of waste treatment problems are incorporated into modern Eimco - Process equipment for gravity and flotation clarification. Even such troublesome wastes as refuse from poultry processing are being handled successfully.

Eimco - Process equipment for treatment of waste waters is available in sizes of a few feet in diameter up to 300 feet. All Eimco-Process treatment units are custom-built for the specific needs of your particular job.

Cooperation of Eimco - Process with consulting engineers during plant design can be most helpful. When the United Air Lines maintenance base at San Francisco was faced with an oil separation problem that an installation of gravity separators could not solve, discussions with the airline's consulting engineers resulted in a plant equipped with Eimco-Process pretreatment and flotation mechanisms in tanks that remove free and emulsified oils from waste waters before disposal into the airport sewer system.

Additional facts on waste water treatment equipment can be obtained from the Eimco - Process representative near you. Call him or write Eimco's Process Engineers Division for Bulletin SM-1017, describing Eimco-Process equipment for wastes treatment.

Eimco-Process Type B Clarifier Mechanism in 30-ft square tank handles sewage at winter resort. Kennedy Engineers, San Francisco, Consultants.

SQUAW VALLEY RESORT

U.S. Government installation employs an Eimco-Process Type C 40-ft diameter secondary clarifier mechanism. Huntsville, Alabama. U.S. Army Corps of Engineers.

REDSTONE ARSENAL, ALA.

WHEATON COLLEGE

Norton, Massachusetts. Eimco-Process Type ADC Aerobic Digestion plant for 60,000 GPD sewage flow. Weston and Sampson, Boston, Mass., Consulting Engineers.

MOUNTAIN FARMS, INC.

Type ADC Eimco-Process Aerobic Digestion plant for 100,000 GPD poultry waste flow. Hiddenite, North Carolina. Abernethy and Scott, Hickory, North Carolina, Consulting Engineers.

CAA TRAFFIC CONTROL CENTER

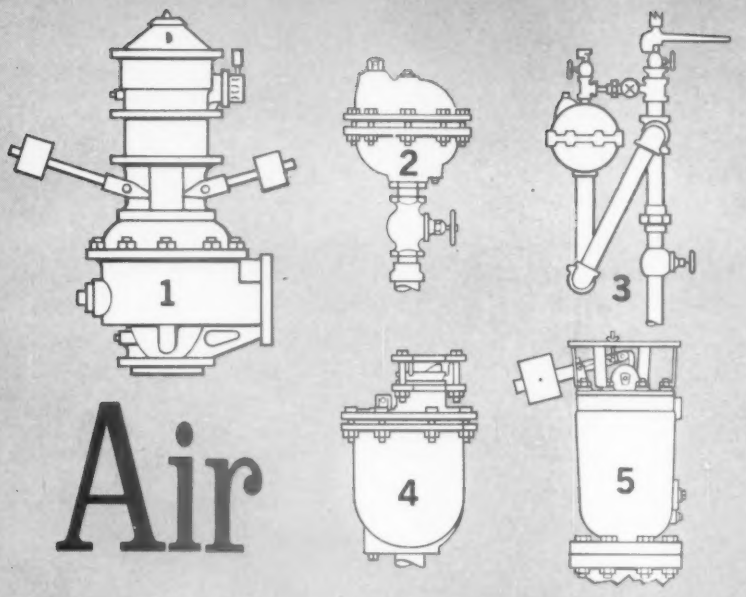
Hilliard, Florida. Eimco-Process Type ADC Aerobic Digestion plant. Civil Aeronautics Administration. Walter J. Parks, Jr., Jacksonville, Florida, Consulting Engineer.

B-636

THE EIMCO CORPORATION

Process Engineers Division

420 Peninsular Avenue
San Mateo, California



Air

How to protect your pipeline from too much or too little of it.

1. Prevents water hammer: Type CCAV Controlled Closing Air Valve protects against damaging effects of surge and water hammer. Combines functions of an air inlet valve (vacuum breaker) and a controlled closing unit (to prevent sudden water stoppage and subsequent water hammer). 4" and 6" sizes. Capacities from 575 to 5980 gpm. Send for Bulletin 1225.

2. Removes excess air: Type AGFD Automatic Air Release Valve prevents stoppages due to air-lock at high points in line. Has large discharge capacity, excess power to insure opening of the valve against high internal pressure. Can be equipped to hold vacuum, preventing re-entry of air into pipeline through valve. Furnished with 2", 1½" or 1" inlet diameter. Standard valve operates to 250 psig—special to 300 psig. For details, send for Bulletin 1206.

3. Protects sewage pipelines: Type "B" Air Release Valve, special for lines carrying sewage or sludge, removes entrained air and gases. Special trap catches sludge, prevents fouling of air release valve. Relatively simple back-flushing cleans out this trap, maintains top efficiency and protection. Valve itself is same as Type AGFD. Details are in Bulletin 1206.

4. Provides three functions: Type AV Air Release and Air Inlet Valve performs three operations, combines great protection and single-unit economy: (1) Automatically releases accumulated air, (2) admits air to break vacuum, and (3) vents pipeline to permit escape of air when filling system with water. Standard units operate to 150 psi. For full details, send for Bulletin 1205.

5. Breaks vacuums: Type VAC Air Inlet Valve solves two serious pipeline problems: possible collapse of pipelines due to formation of vacuums—and stoppage of flow, caused by air binding when lines are being filled. Standard units have 4" to 10" inlet diameters, can be assembled in groups to do the work of one large, expensive valve. For 16 pages of detailed information, send for Bulletin 1202.

SIMPLEX
VALVE AND METER COMPANY
a division of PFAUDLER PERMUTIT INC.
Lancaster, Pennsylvania

TESTS PROVE:

NEW JOINTING MATERIAL LASTS LONGER THAN SUBSTITUTE PIPE

Lifetime Vitrified Clay Pipe—which is chemically inert and can't be damaged by gases and acids normally found in sewer lines—has been the standard of excellence for centuries.

But how about the new resilient jointing materials now being used on Clay Pipe? How do they stand up under acid attack?

Samples of standard jointing material have been suspended in sewer lines in cities all over the country to see how they react to normal exposure. But we wanted to find out quickly if they stand up to sulphuric acid—the number one killer of sanitary sewer lines built of substitute pipe.

In one test, samples of cement-asbestos, concrete and clay pipe and five jointing materials were weighed dry, then exposed to a five-percent sulphuric acid solution for 100 days. They were then removed from the acid, dried, and weighed again to observe weight loss and disintegration.

The results were amazing!

The sample of concrete pipe was completely disintegrated. The sample of cement-asbestos pipe was badly laminated and almost disintegrated.

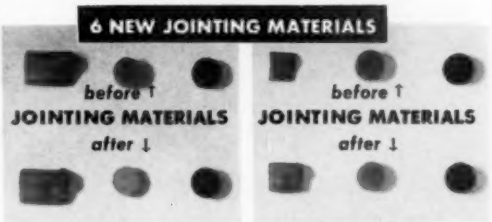
But there was no evidence of any deterioration of either the jointing materials or, naturally, the Vitrified Clay Pipe.

Get all the facts* before you specify any kind of pipe for your community's sewer line. There's no substitute for lifetime Vitrified Clay Pipe with the new compression joints.

**Further explanation of this experiment is available on request.*

Pipe and jointing materials after 100 days exposure in 5% Sulphuric Acid Solution

6 NEW JOINTING MATERIALS



Unretouched photographs made at the NCPMI Research Laboratory

COMPRESSION SEALED, VITRIFIED
CLAY PIPE
IMPERVIOUS
THE STANDARD in SANITARY SEWERS

NATIONAL CLAY PIPE MANUFACTURERS, INC.
1028 Connecticut Ave., Washington, D. C.
Please send me full details on the new factory-made compression joints on Clay Pipe.

(name)

(company)

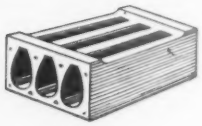
(street address)

(city and state)

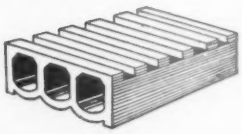
8-21 WP

NATIONAL CLAY PIPE MANUFACTURERS, INC.
1028 Connecticut Avenue Washington 6, D. C.

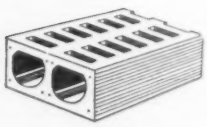
WHY TRICKLING FILTERS SUCCEED for Sewage and Wastes Treatment



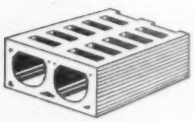
NATCO
Natco Corporation
Pittsburgh 22, Pa.



TRANSLOT
Connelton Sewer Pipe Co.
Connelton, Ind.



ARMCRE
Ayer-McCord Clay Co., Inc.
Brazil, Ind.



BOSCO
Bowerston Shale Co.
Bowerston, Ohio

Nearly 1,000 new trickling filters went into service between 1945 and 1957. The building-pace continues unabated. This is a direct reflection of their economy in construction and efficiency in operation. For many of these filters are working as well today as when first built, even those thirty and more years old. Costly remodeling and rebuilding have been avoided. And no other type is easier to add to if growth exceeds your original estimate.

An important element in this success has ben the vitrified clay underdrain blocks in the floors. Clay leads the field in its resistance to corrosive factors such as acids, alkalis and bacteriological action. TFFI Specification clay blocks not only serve right, they are made right—in modern plants under manufacturing controls of quality that substitute materials cannot even approach.

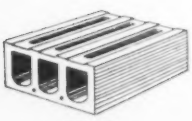
Demand Certified Underdrain Block!

Vitrified Clay Block manufactured by TRICKLING FILTER FLOOR INSTITUTE members and tested by the Materials Testing Laboratory of Rose Polytechnic Institute comply with or exceed ASTM Specification C 159-59T.

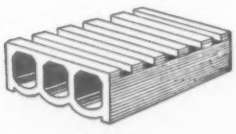
Only TFFI blocks give you a 50-year Guarantee.

TRICKLING FILTER FLOOR INSTITUTE

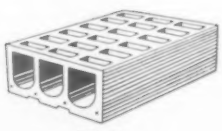
Address nearest member



POMONA
Pomona Terra-Cotta Co.
Pomona, No. Car.



TRANSLOT
Texas Vitrified Pipe Co.
Mineral Wells, Texas

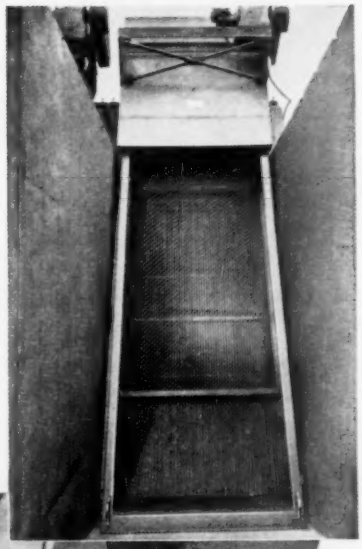


DICKEY
W. S. Dickey Clay Mfg. Co.
Kansas City 6, Mo.

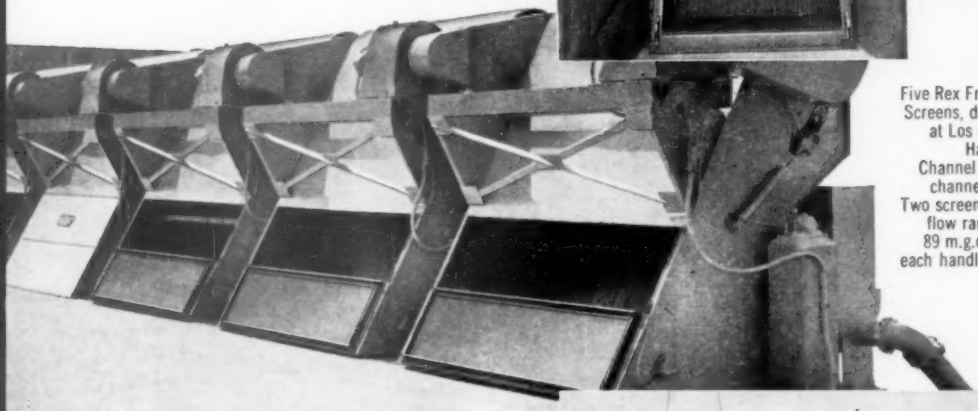
Rex Front Cleaned Bar Screens with a Pivot

Provide Maximum Flexibility for Los Angeles County Plant

In the Los Angeles County Sanitation District No. 2 Sewage Treatment Plant at Harbor City, a new concept in screening operations has assured a new high in efficiency and flexibility...a new low in operating and maintenance costs...Rex Front Cleaned Bar Screens, designed to pivot.



Close-up view showing screen suspended in channel. Note neat appearance... totally enclosed, streamlined housing and "straight-through," unobstructed flow.

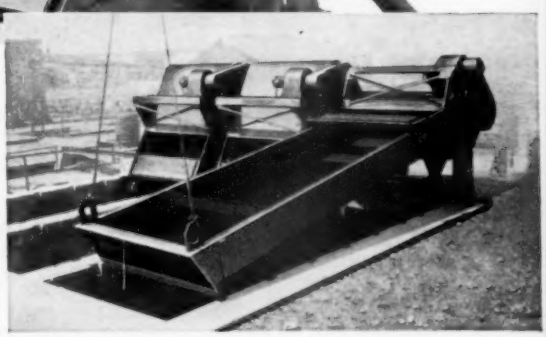


Five Rex Front Cleaned Bar Screens, designed to pivot, at Los Angeles County, Harbor City Plant. Channel width, 6½ feet; channel depth, 16 feet. Two screens each handle a flow ranging from 30 to 89 m.g.d. Three screens each handle flows of 42 to 127 m.g.d.

With this advanced design, each screen is pivoted so that it can be easily swung out of the channel for inspection and servicing. No need to dewater the channel...no need to shut down operations. Screens are back in service in a hurry.

FRONT CLEANING... front-mounted rake is held firmly in place...provides maximum shelf for carrying capacity. Positive, complete cleaning of tops and sides of bars to their full depth. Rakes *and* teeth clean the bars. No chance for rakes to slide over, or miss, screenings. Bar rack is held firmly in place at top and bottom to maintain uniform spacing.

MAXIMUM EFFICIENCY. Full 60-degree inclined racks mean greater rack area exposed to the flow. Dead plate from bar rack to point of discharge eliminates spillage...no screenings on downstream side. Chain Belt Company, 1606 W. Greenfield Ave., Milwaukee 1, Wis.



Screen pivoted out of channel. Pivot shaft rides in heavy-duty angle pillow blocks mounted on concrete pedestals.

REX®

CHAIN BELT COMPANY

FLUIDICS* AT WORK

How to increase aeration capacity without adding new tankage

Here is the new activated sludge system at York, Pa. Sewer Authority. Plant capacity is higher than ever before, yet not a cent has been spent for new basins.

Four Permutit® Permaerators make up the heart of the system. The unit you see being installed is capable of transferring 115 lb. of oxygen per hour with a compressed air flow of only 420 cfm.

High efficiencies of this type are possible by utilizing atmospheric air entrained by the upper turbine of the Permaerator. In addition, the upper turbine redisperses compressed air released from a sparge ring beneath the lower turbine.

Albright & Friel, the consulting engineers, recommended Permutit Permaerators because of their high efficiency, rugged construction, and low initial cost. By the installation of four Permaerators, the system's ability to handle higher hydraulic and biological loadings was significantly increased. Since Permaerators are adaptable to old as well as new basins, this increase in treatment capacity was achieved without construction of any additional tankage.

What York has done, you too can accomplish. If you need to increase the capacity of your activated sludge plant with a minimum of capital expenditure, consider the Permutit Permaerator. For further information, write for Bulletin 4619. Permutit Division, Dept. JWP-31, 50 W. 44th Street, New York 36, N. Y.

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.

Twin-turbined unit being installed here is one of four Permutit Permaerators now in use at York, Pa.—one in each of two aeration tanks, and two in the return sludge stabilization tank.

PFAUDLER PERMUTIT INC.
Specialists in FLUIDICS . . . the science of fluid processes

"Flexible" CAM DRIVE UNIRODER

An entirely new principle providing Non-Slip Rod Drive!

NO ROLLERS TO SCORE OR BURN

ANOTHER *"Flexible"* FIRST!

PAT. PENDING

UniRodeR Model SUR-1 rods sewers and is ideal for threading cable for bucket machines

CAMS GRIP TIGHTER UNDER LOAD

Revolutionary! Traveling cams push or pull the continuous rod, rotating with it in either direction. The heavier the load the tighter the cams grip the rod. NO FRICTION ROLLERS TO SCORE OR BURN. Exclusive Safety Overload Clutch protects pipe, machine and rod. Simplified mechanism and fewer working parts mean less maintenance than any other continuous rodder!

- 8 Speeds Forward or Reverse
- Positive Non-Slip Cam Drive
- Capacity up to 2000 ft.
- Tool Box, 3 cu. ft. Capacity
- All Moving Parts Enclosed
- Safety Overload Clutch
- Footage Meter
- Uses From ¼ to ⅜-in. Rod
- 9 hp. with Self Starter

FLEXIBLE INC.

415 S. Zangs Blvd., Dallas, Texas

Factories: Los Angeles, Calif. and Lima, Ohio

SONOCO
P.I.
PITCH-IMPREGNATED
PIPE

Costs reduced in natural process waste disposal system

P.I. PIPE comes in 10' lengths up to 36" I.D.; straight line fibre couplings available with or without neoprene gaskets. Can be sawed, or drilled and tapped for special fittings. Steel fittings may be connected to P.I. PIPE with Dresser or other similar couplings.

Bubbling orifice natural waste disposal system of John H. Dulany & Son, Inc., Fruitland, Maryland, vegetable canners. Designed and engineering by C. W. Thornwaithe Associates, Elmer, N. J. From the supply main, cannery waste effluent flows into buried distribution laterals, and bubbles to the soil surface through short risers, spaced every 20 feet. This waste is then purified by natural filtration and absorption.

Because of its low initial cost, ease of installation, and resistance to corrosion, over 11,000 ft. of P.I. PIPE was used in this "bubbling orifice" waste disposal system, installed at John H. Dulany & Son, Inc., frozen food packer.

SONOCO P.I. PIPE is the newest development in fibre pipe—and the *only* fibre pipe available in I.D.'s up to 36 inches! It has particular value in industrial waste disposal systems because it is strong, low in cost, and impervious to harsh chemicals found in soils and effluents. In fact, with its ease of installation and great durability, P.I. PIPE can be used with excellent results for all types of gravity flow lines where the maximum head does not exceed 20 feet. It also is ideal for industrial venting.

Wall thicknesses of P.I. PIPE can be varied in any diameter to meet your specifications for crushing strength. This means you get the best possible pipe for your needs . . . at the lowest possible cost.

The next time your plans include a non-pressure or low pressure pipe line, specify SONOCO P.I. PIPE . . . and save time, labor, replacements, *and money!*

For complete information and prices, write

SONOCO 4877

Construction Products

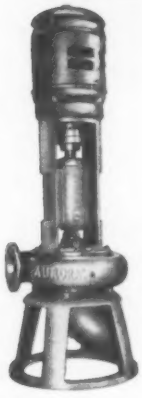
SONOCO PRODUCTS COMPANY • HARTSVILLE, S. C.

OBJECTIVE PERFORMANCE

. . . EFFICIENCY AND ECONOMY WITH

AURORA® *Heavy Duty*

NON-CLOG PUMPS



TYPE KUC VERTICAL—For compact installation with flexible coupling drive...motor high above floor.

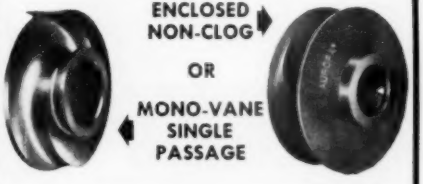
TYPE KCM VERTICAL—Utmost compactness...close-coupled design...low suction.

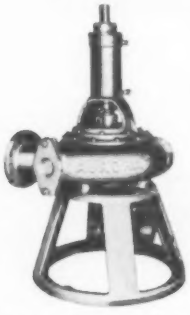
For handling heavy liquids . . . and solids in suspension. Ideal for public utility and industrial wastes.

Capacities to 9000 GPM • Heads to 150 feet • Solids size to 6 inches

- Easy Installation
- Easy Disassembly
- Smooth—Quiet operation
- Hand cleanout provided in casings
- Detachable suction and packing covers
- Large Passageways
- Many optional features available
- Uniquely balanced impellers
- Engine or combination drives available
- Deep packing boxes

ALTERNATE IMPELLER DESIGN





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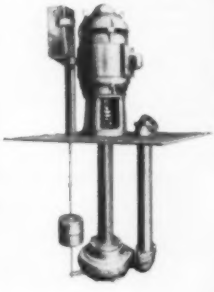

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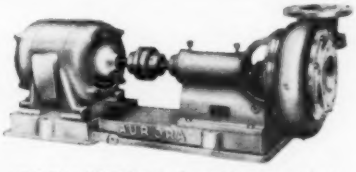

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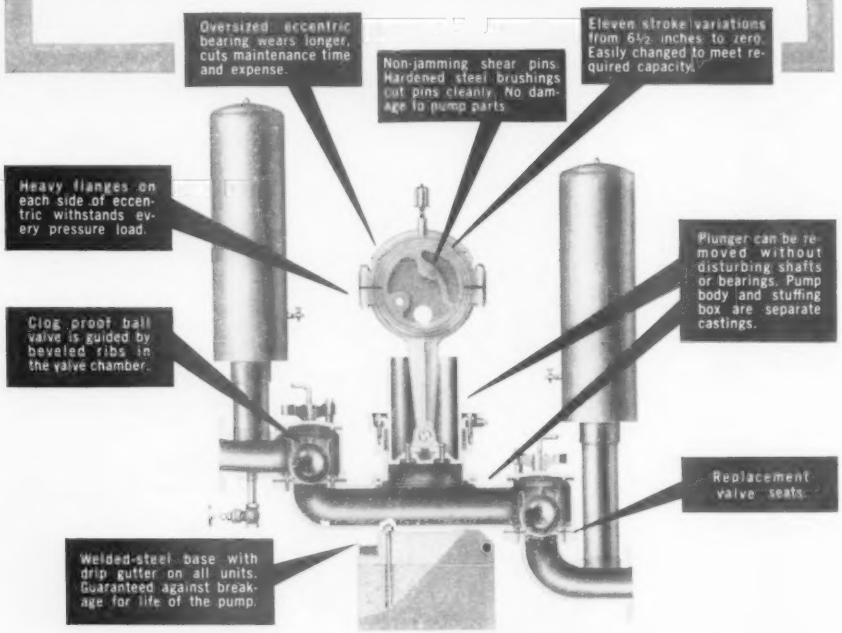
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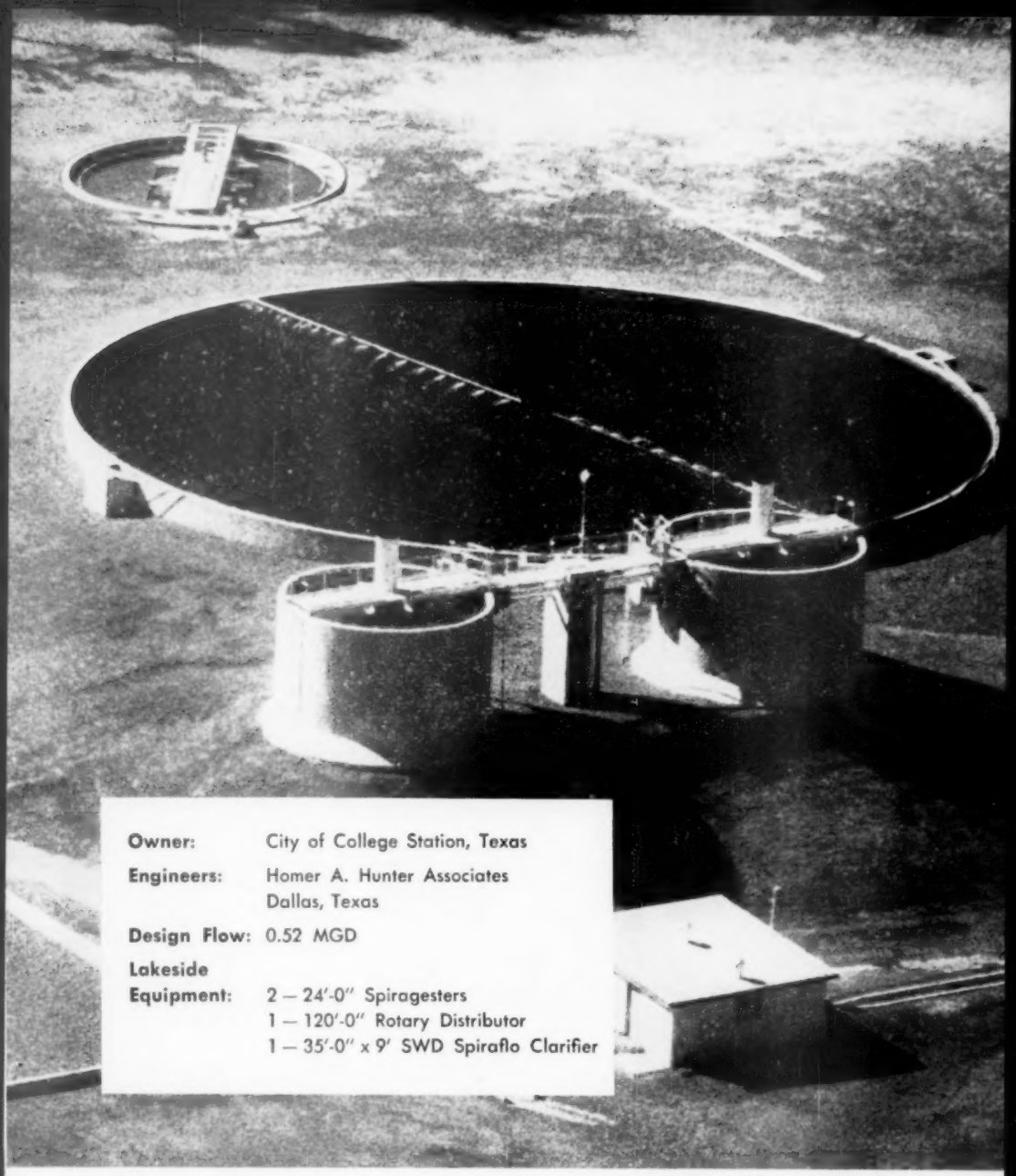

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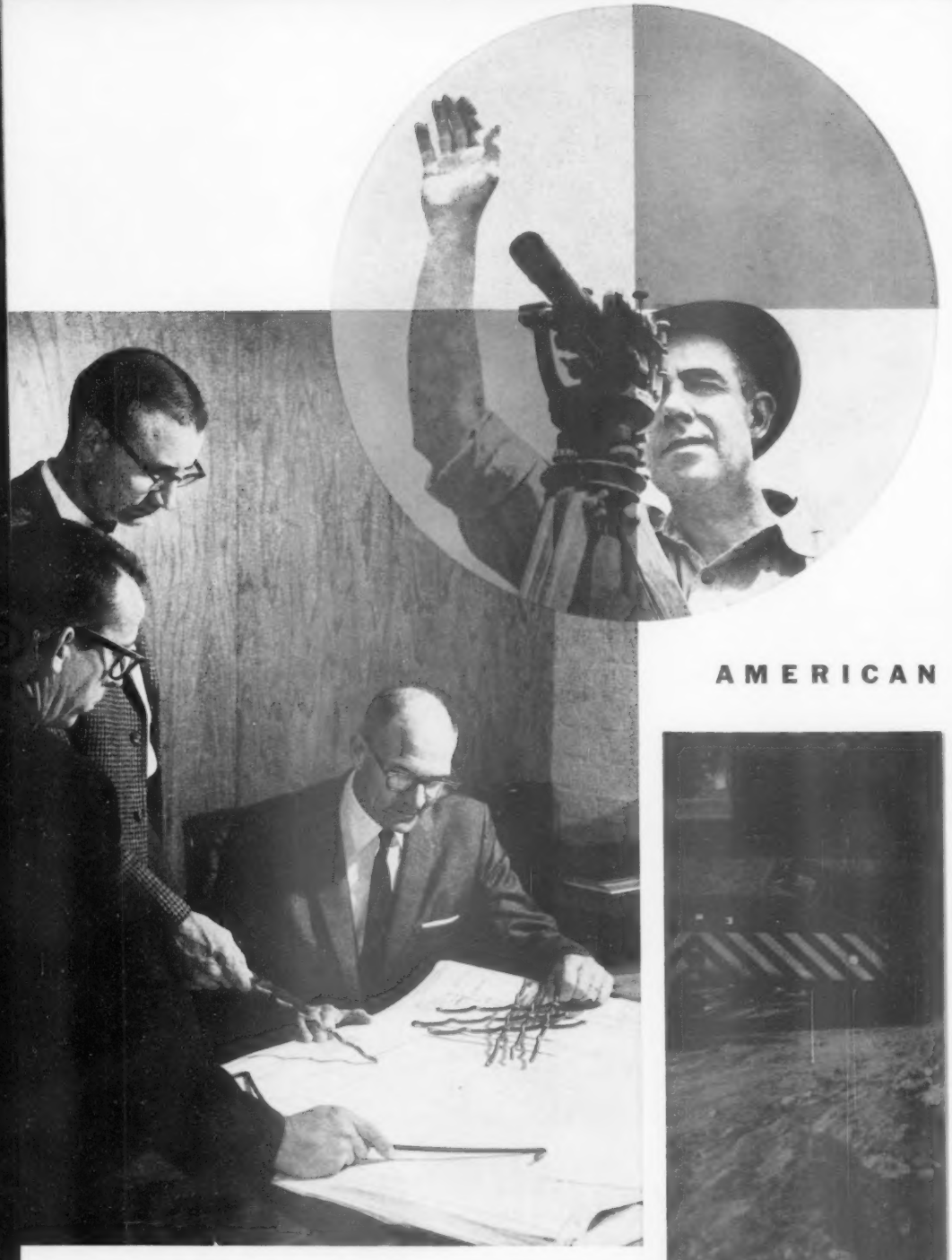

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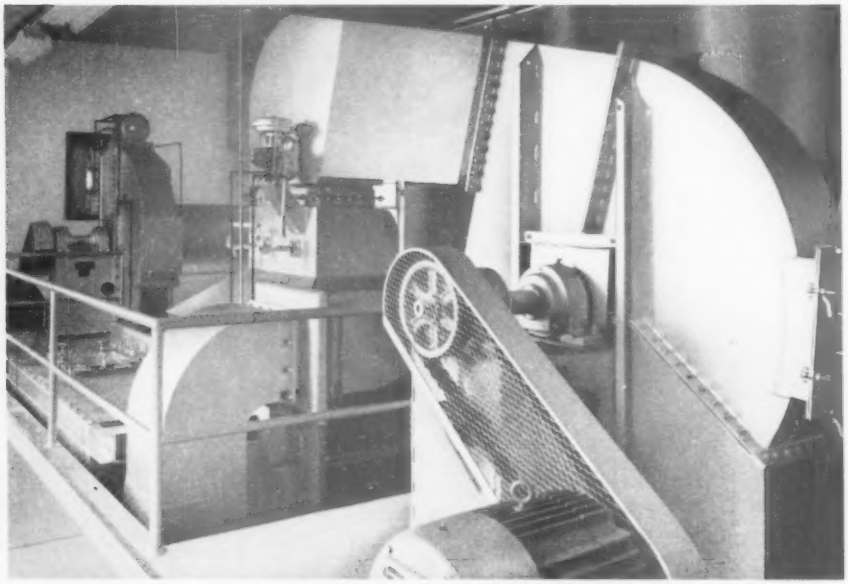

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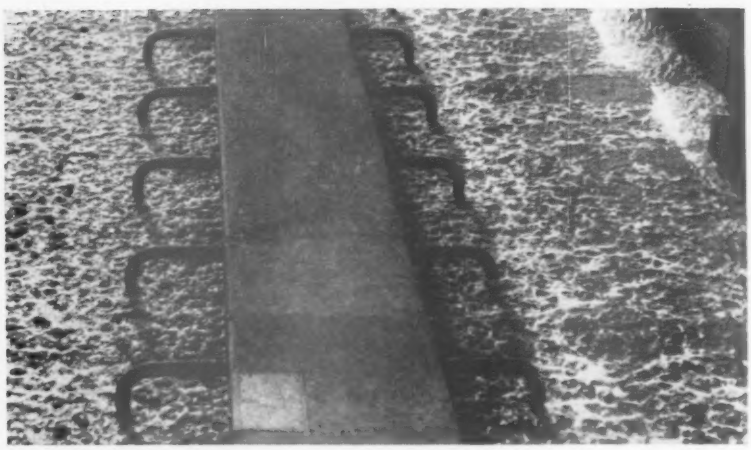

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THE WATER POLLUTION IMAGE

M. D. Hollis

If there is general agreement that water pollution results from concentrations of people in a progressive dynamic economy, then certainly it should surprise no one that today this is an involved and complex problem. This is simply in keeping with the tenor of the times. A requisite need, perhaps, is to break down barriers of provincialism, the prejudices of proprietary interests, and varieties of narrow traditional points of view, too commonly shared by so many.

Representative at this assemblage, for instance, is an amalgamation of water pollution interests. This certainly is proper and is indeed as it should be. Some of these interests have long been known to coexist with something less than brotherly love. Interwoven in this problem are sources of friction—ingredients for dissatisfactions. But as citizens all, there is reason to believe that among this group there is something approaching a common denominator of basic concerns and aspirations, even though at times it seems a bit remote.

What is now important is to see if this national conference can stimulate something beyond a cool air of coexistence. To see if there can be a modification of the spirit of competing interest, of conflicting interest—to something more akin to a spirit of allied interest, of common goals, and common objectives. This is needed to remove the feeling of incompatibility between the reasonable protection of the Nation's waters and the obvious necessary use of these same waters for the final disposal of liquid wastes.

If such differences can be resolved, the result should contribute significantly to a long overdue, much needed, clear "mission for the sixties." Certainly such an objective is important, and it is timely on this eve of a new year and on this eve of a new decade.

The Problem

The first consideration is to ask why there is a pollution problem. For simplicity, this is discussed on a national composite basis. A reminder is that for any given watershed and for the Nation as a whole, average surface water supplies are constant. So much water falls on the earth. Here it divides among ground storage, evaporation, transpiration, runoff to streams, and finally discharges to the oceans. Land use practices alter runoff patterns. Impoundments modify rates of downstream flow. In the water cycle, these are significant influences, but they do not change over-all quantities.

The situation in 1900 is first considered. Urban population was 30 million. The population using surface water supplies was 2 million. Treatment provided was settling and filtration. Sewered population was 25 million, but there was practically no treatment. Wildlife and recreational values were relatively unimpaired.

The author is Assistant Surgeon General and Chief Engineer of the Public Health Service, Department of Health, Education, and Welfare, Washington, D. C. He was the 1960 President of the Federation.

The paper was presented at the National Conference on Water Pollution in Washington, D. C., Dec. 12–14, 1960.

By 1920, urban population had increased to 54 million and those using surface water supplies, to 20 million. Coagulation and chlorination were added to water treatment practice. The sewered population increased to 50 million, 10 million of which were provided some crude treatment. Rumblings were heard about localized pollutional nuisances—about wildlife and recreational impairments.

By 1940, the urban population was 80 million. At that time 40 million people used surface streams for drinking water. Water treatment was improved. The sewered population was 70 million with about half being provided sewage treatment. Secondary treatment became more common. Chlorination of sewage effluents was added in some cases. However, the total stream flow remains essentially constant. Localized pollution was more pronounced and extended. Resort areas were affected. Progressive deterioration of streams became a recognizable factor, public indignation increased.

A pause at 1940 is in order. A delineation of pollution from city sewers and from industrial operations and its impacts are discussed as follows:

1. Biological contaminants. These are living organisms, germs of all types, including those with the deadly potential of causing outbreaks and epidemics of human diseases. This is a continuing public health concern. The source is mainly household waste, more specifically, human sewage. With dilution, and time, harmful germs ultimately die off in the stream. Chlorination of sewage effluents reduces the numbers of living organisms.

2. Organic contaminants. These are composed of unstable material that utilizes dissolved oxygen in the stream in the natural process of stabilization. The dissolved oxygen supports the type of bacteria needed to consume the organic matter. Thus, streams have the ability to cleanse themselves of organic pollution, if such loadings are not too heavy. Below points of such pollution the oxygen in the stream is used up, generally much faster than it is replaced. Within limits, and with time, the stream recovers from the shock of such pollution. On the other hand, if overloaded, the dissolved oxygen in the stream is depleted; fish die, the aquatic balance is upset, and the stream becomes literally a sewer and a cesspool. In a sense, it becomes useless water. The source of organic pollution is largely cities and industries.

3. Inorganic pollution. These are acids, alkalies, and salts from mining operations, oil fields, metal plating, and a host of other industrial and commercial pursuits. Such pollution is persistent, and where excessive, degrades stream usage. Dilution modifies the effects.

As to 1960; World War II gave great impetus to metropolitan and industrial growth. Urban population is now 126 million—up 55 per cent over 1940. The population depending on surface streams for drinking water is 100 million—up 150 per cent over 1940. The sewered population is 105 million, with 80 million subject to varying degrees of waste treatment.

Effects of the War

Prior to 1940, there was a somewhat orderly transition from a rural to an industrial economy. Cities were still separated entities, generally with appreciable distances between shocks of pollution. Industries were in or near cities. Pollution, for the most part, was natural organic materials with concentrations of biological contaminants. Improvements in water treatment and extension of waste treatment kept the scales reasonably in balance. Excessive pollution, where it occurred, was still largely localized and over short stretches of streams.

Since 1940, three major influences

aggravate the pollution situation. All three are World War II related:

1. There was a fantastically increased tempo in the transition to metropolitan and industrial development—the formation of gigantic metropolitan complexes extending hundreds of miles generally following major water courses. Industries go where there is water and populations build up where there is industry.

2. There was practically no construction of municipal or industrial waste treatment works over the period 1940 to 1947. Men and materials were needed for the war effort.

3. The avalanche of technological progress brought with it a whole array of new-type contaminants, such as synthetic chemicals and radioactive wastes. Production and use of such materials continue upward at substantial rates.

Future Trends

By 1980 the urban population will be in the 200-million range. The population depending on surface streams for drinking water will be about 165 million. The sewered population will be at 200 million. It is assumed that all waste will be treated. Average stream flows will be the same. For most streams the waves of pollution shocks will become somewhat additive; there will be little time for the stream to recover between such shocks. Distances between waste outfalls and water intakes will be wedged closer and closer together. Hundreds of new type, more persistent pollutants will further complicate the situation.

The pollution image will broaden and likely it will darken. At the same time water needs will spiral upward toward astronomical figures. Repeated reuse of waters will become the rule, not the exception. Three-fourths of the 1980 population will live in metropolitan areas. Six-times reuse of the same water must be anticipated. What then will water quality be like? What will the stream environment be like? What about recreational and aquatic values? These are pertinent questions.

This representation of composite stream and urban development obviously is an oversimplification. For one thing, it does not include the industrial waste picture. Accurate data simply are not available, but industrial growth since 1940 has been much more phenomenal even than metropolitan growth. Further, there are wide variations between streams as to the type and extent of pollution as well as stream usage and needs.

In the past there has been heavy dependence on dilution water—"solution by dilution." What about supplementing stream flows? There is general agreement that, as a continental unit, the Nation actually has enough water. The problem is one of poor distribution, both geographically and seasonally. Within a given watershed, impoundments can do much to even out flood flows, but there are practical limits.

How feasible is it to redistribute water between watersheds? The more realistic method is the laborious one of transporting water on the ground. On this, intriguing possibilities come to mind. Envision an interlacing interbasin network of canals and conduits fed by surplus flood waters from major rivers and, even more enticing, fed by waters from the Great Lakes. In terms of engineering feasibility, cheap power would be the key.

But before becoming too ecstatic in flights of fancy, practical, legal, and political realities must be reckoned with. Diversions of waters from natural watersheds introduce fundamental questions of economics, basic water law, water doctrines, and ownership of water. Already, there are innumerable examples of these conflicts where such diversion is practiced or proposed.

The conversion of sea water has intrigued scientists over the ages. While striking progress is being made, the

practical economics of desalting and the major logistics of transportation, place this means of augmentation at some distant future and with limited application. This is certainly true in terms of inland areas and general water needs, such as more water for dilution of waste.

The science of weather modification, to supplement rainfall by artificial means, has been suggested. Without debating the pros and cons, the practical application of this science, as a substantial adjuster, is a long way off.

Accordingly, for the predictable future, reality seems to dictate, for the most part, the necessity for using what is now at hand, basin by basin; that completion of the network of impoundments to even out flood flows be accomplished; that work be done toward the more equitable use of water; and finally, that the most reasonable method of "providing" more water is to "save" more water. And the best way to save water is to avoid excessive pollution of streams. There is always a return to the basic necessity of effective treatment of sewage and waste as a practical means to reduce pollution, and to preserve water quality for repeated reuse as streams flow from headwaters to the oceans.

Actual Status Today

Now, what is the status today? A hundred million people depend on surface streams for drinking water; 105 million are connected to sewers discharging essentially to these same streams; industrial growth is accelerating; aquatic recreation is in higher demand.

Remember that waste treatment is partial treatment—not purification. Treatment is designed to condition the waste, and reduce its pollutional shock, with the stream completing the job. For most areas, this concept is still workable and will so remain for the predictable future. Economically this is important, because costs are quite high for advanced stages of treatment. On the other hand, in some areas, the composite residual loadings after treatment are already overtaxing stream capabilities. This situation will become common in the years ahead. Improved treatment will be needed. This is one of the several new situations that must be faced as progress is made toward the bright new world.

Public Health Aspects

Now, what about the public health implications of the changing pollution picture? In man's contemporary environment, contaminants in air, water, and food are becoming somewhat interrelated in their impact on health. Earlier in the century public health practice focused on the microbiological factors causing diseases in man. With respect to water supply and sewage disposal, attention was directed, and properly so, to the problem of controlling germ diseases, largely enteric infections. This effort has been brilliantly successful—water-borne epidemics and outbreaks have been virtually eliminated. Communicable diseases continue to be a plague; problems will be aggravated with population concentrations. The safety factor grows correspondingly thinner. But it should not be too difficult to strengthen the protective barriers. Deficiencies in handling biological contaminants will be due largely to shortage of vision and to apathy, not lack of scientific know-how with time-tested practical application. The problem of viruses does represent an exception.

The post-war focus of public health has broadened to include major attention to the chronic impairments of man —to changing environmental stresses. Fair has stated, ". . . there is a significant difference between the environmental stresses of the nineteenth century and those of today; those of a century ago were allied principally to microbiological factors; those of today

have their source in microchemical substances."

New Contaminants

Today metropolitan and industrial wastes are huge in volume and include increasing amounts of new-type synthetic chemical contaminants. Most of these wastes were practically non-existent in 1940. Now they are present in concentrations up to 0.5 mg/l in several major streams. These synthetic organics do not break down like natural organics, they are persistent over long periods, and to a large extent, they are not removed either by sewage treatment or by normal water purification practices. There is much to learn about the behavior of these new contaminants in streams; their relationship to natural stream purification phenomena; and their long-range subtle effects on public health, on aquatic life, and on municipal and industrial water supplies. They add the question of toxicity to the age-old problems of typhoid fever and similar diseases.

The buildup of these complex conglomerates in streams and even their low-level existence in drinking water in itself is no basis for alarm. But certainly it must be learned what these materials are and how to measure them. More must be learned about the long-range chronic effects; about combinations and about synergistic potentials. Radioactive waste is another contaminant introducing new problems, new dimensions, and new headaches.

This aspect of the pollution situation is characterized more by what is not known than by what is known. This is not the type of problem that should be "swept under the rug" and forgotten. It needs to be in the open and it needs to be worked on. For when trends are projected for a decade or two, this aspect of pollution does have sobering implications and creates a real sense of urgency for research action now. The public health aspect of water pollution again moves front and center.

Contaminants from Runoff

In a word, sewered waste today is a vastly complicated material, compared to what it was before 1940. This points up the second of the new situations. Another contributing factor, as yet undiagnosed, is the impact on stream usage of non-sewered contaminants; for example, the residue from some 500 million pounds of synthetic pesticides produced annually for agricultural practice.

This is an era of accelerating change, with increasing tempos affecting almost every facet of daily living. Pollution control in the past has been largely corrective. In the future it must be preventive. Remedial measures must replace corrective actions. The tenor of the times and the complexity of the problem simply outmode the philosophy of postponement. The present so soon becomes the past that continually, from here on, work must be done with a critical eye to the future.

When 1980 or 1990 is considered, no longer is it some dim future that the next generation might worry about. On water pollution, the need for clear concepts and principles, for stepped-up research and bold action cannot be postponed. This need is not tomorrow —it is today. Perhaps even it was yesterday.

Recreation and Aquatic Life

With respect to recreation and aquatic life, pollution has progressively degraded these values in most areas of the Nation. Degradation runs the gamut, ranging from impairment of natural values, to destruction of fish-food chains, to periodic fish kills, and to extinction of beneficial aquatic life. By way of exception, there are excellent examples, such as the Schuylkill River in Pennsylvania, where degradation has been reversed and a desirable natural balance restored. The favor-

able economics of this action is a matter of record.

There is certainly little doubt of increasing public demand for preservation and recreational use of water resources. One need only review the statistics on boating equipment, aquatic sports, fishing, and hunting paraphernalia to be convinced, both of public attitude and measurable economic potentials.

But now a caution—it must be remembered that increased leisure time and high standard of living, which enable Americans to enjoy these recreational pursuits, have their roots deep in the industrial-technological economy. The by-product liquid wastes from man and machines and runoff drainage ultimately must be discharged to streams. Accommodation of this reality in many congested areas will limit the practical extent that all natural values can be preserved.

It must be recognized that to enjoy the great advantages of modern technology there must be acceptance of some of the consequences. Pollution is one of these. But the pollution impact from human activity in these areas of "wall-to-wall" people can be moderated—and it must be moderated. How clean and pure the attempt is made to maintain streams is a matter of economics and realities, and of values both tangible and intangible. If the objective is pristine purity for purity sake, it is easy to "price" the public out of progress. On the other hand, if the objective is solely the dollar sign, continually to undercut the necessary cost of controls, it is easy to "prosper" the public out of critically essential water resources. Between these extremes come the tough hard choices.

How Far?

To say it costs too much to prevent excessive pollution is just plain nonsense. But there is needed a clear understanding and a clear definition of "excessive." Obviously, pollution must be kept below the levels of significant personal health damage. It should be kept within bounds that do not destroy recreational and wildlife values. It is desirable to keep pollution within bounds which preserve the natural stream habitat. For every stream, each of these levels has its corresponding price tag—and it is sure that the cleaner and purer, the higher the cost. And present cost will move upward where there are ill-advised, indiscriminate watershed developments.

In other words, while there are limits to what can be accepted as technological progress, there are also limits to how far such progress must, or will, yield to desirable but less than critical aspirations. The difficulty always lies in identifying limits. Certainly these cannot be generalized; necessarily they will vary, from area to area, and from stream to stream, depending on the state of development and other realities. This emphasizes the need for development of truly comprehensive water use programs—basin by basin—with some means of assuring strict adherence to the agreed-upon plans and objectives. With a few exceptions, this is not now in existence.

Need for Reality

Water pollution is an involved, complex, economic, technical, and political issue. It must be dealt with in terms of realities of the times. Metropolitan growth and technological advances are predominant influences. Volumes of waste spiral upward—the composite types and character of wastes are becoming more complex and more difficult to handle. Water needs and stream usage are increasing at unprecedented rates. Average stream flows remain essentially constant. This is a vicious cycle—more men and machines demanding more water to produce more pollution to degrade these same waters. Specific remedial actions should be

based on specific cases. Simple generalizations are to be avoided, except as a reflection of the pollution image. Otherwise there are warped answers, unbalanced equations, and a great deal of frustration.

For example, if runoff waters were uniformly spread throughout the streams of the Nation and if polluting wastes were similarly apportioned, there would be no major pollution problem and no major water use problem. But this is not the situation.

Today, while water pollution varies widely in different areas, it is being held generally within livable limits. But there is a tough job ahead—and a continuing one. The annual rate of constructing municipal sewage treatment works has now about doubled over the 1950 to 1955 average. Much of this construction has been in congested areas such as the Ohio Valley, the Delaware Valley, and coastal tributaries. There are innumerable examples where sewage treatment works of recent vintage have improved the oxygen conditions below metropolitan centers and where bacterial pollution (as measured by *B. coli*) has been notably reduced. This is real progress—it literally has averted cesspool conditions in these areas. Industries, too, have done a great deal in an effort to keep up with the fantastic growth rate of production. But even as these actions are taken, the growth pattern continues.

Present and Future Needs

In these times it is necessary to run faster and faster to stay in the same place. Annual construction should be $600 million—up 50 per cent over the current rate—to take care of the backlog, the increasing sewered population, and obsolescence. The latter will increase substantially in the sixties. Assuming the industrial waste load as equal that of municipalities—and certainly it is no less—this means a construction rate of more than a billion dollars per year on into the future. There is no substitute—it must be faced.

Actually, is this situation substantially different from the growing needs for highways, for schools, for hospitals, and other public works? Isn't this the price range that should be expected in this accelerating technological society? Should not the public be willing to bear the reasonable cost of municipal and industrial waste treatment, through some suitable mechanisms, as the price to preserve streams?

In many areas, the question of "willingness" becomes somewhat academic. More treatment will be essential to protect drinking water and to preserve some semblance of wildlife and recreational values. For decades far too little of the public works dollar has been apportioned for sewage treatment. There has been much argument about the pollution image, but much less done to balance the scales.

Again, it must be kept in mind that present construction provides for partial treatment, a sort of "cosmetic" treatment to eliminate unsightliness—to reduce the more acute effect of pollution shock below points of discharge. By way of example, compare municipal pollutional discharges of 1960 with 1940. Sewered population is up 50 per cent in 1960 over 1940 (from 70 to 105 million). At present, 25 million discharge sewage with no treatment, compared with 30 million in 1940. A composite of the Nation's sewage treatment plants (in 1940 and 1960) reduces organic pollution by about 50 per cent. Accordingly, in 1960 there is 30 per cent more organic pollution load on waters than in 1940. Projecting this simple arithmetic to 1980, at present trends, the organic pollution load will be up another 55 per cent over 1960 or 100 per cent over 1940. Remember that this is just municipal waste, does not include industrial waste, nor do they include synthetics or radioactive waste. This example is

cited to emphasize that this discussion is not about eradicating pollution; it is about confining it—limiting its impact on legitimate stream usage.

Summary

In summary, at least five factors need to be underscored:

1. There is less and less justification for any city or industry to discharge untreated sewage and waste to the waters of the United States, especially the inland waters.

2. For most cities and industries, the treatment requirements will shade upward from primary treatment (35 to 50 per cent reduction in organic pollution) to at least secondary treatment (75 to 90 per cent reduction in organic pollution). Chlorination to reduce bacterial pollution will become the rule in many areas.

3. It is important to accelerate promptly the rate of constructing treatment works to the level required to erase backlog and to keep up with growing needs and obsolescence.

4. A substantial program of research with three primary objectives is needed.

   (*a*) To assess the public health significance of the growing array of new-type contaminants.

   (*b*) To develop practical methods for measuring and for removing dissolved pollutants—for application where wastes have serious toxic potentials.

   (*c*) To develop practical supplemental treatment methods to stabilize further the effluents from conventional treatment. This is for application in those areas where stream use justifies almost completely stabilized organic discharges.

5. Considering pollution from all sources, there is real need to update the national system of monitoring streams. Actually this is the only practical way to maintain a check on existing conditions and trends in stream quality.

In these five items there is nothing inconsistent with formal positions taken by numerous national groups interested in water pollution. Further, as to immediate treatment needs for specific cities and industries, for the most part these have been set forth by responsible state and interstate water pollution control agencies.

The real problem is to gear-up implementing actions in phase with the swift moving trends of the times. A great deal is now being done, but certainly not enough. Financing obviously is the key, to provide resources for intelligent action by official agencies and to provide for constructing waste treatment works. The difficulty is to "catch up" with treatment needs; after that, to "keep up" should be less involved.

On water pollution all have much in common and much at stake. Water pollution control is now big business—it's important business and it's urgent business. On a tonnage basis, waste treatment is, by far, the biggest business in the United States. In far too many areas it has been a neglected business. The only way to control pollution is to treat wastes, and this costs money—lots of money. With few exceptions, this money is not willingly spent. Hence, public understanding is essential—and this must be backed up by effective regulatory controls. Just where the authorities are placed, the extent, and how they are applied, raise basic questions of public policy. Methods of financing essential treatment works, of supporting necessary research and development, are also public policy issues.

Again, this points up the great need for public understanding and public awareness. This is a challenge and an opportunity to speak out on the pollution situation. The objective should be to alert, not alarm—to clarify, not confuse. As progress is made, Mr. Citizen should be kept in mind, because so much depends on what he thinks, and wants, and is willing to pay for.

VOLATILE ACID TOXICITY IN ANAEROBIC DIGESTION

Perry L. McCarty and Ross E. McKinney

The volatile acids analysis has proven to be one of the most important control tests for anaerobic digestion, measuring the concentration of short chain fatty acids which are formed as intermediate products during the anaerobic breakdown of complex organic matter. It is commonly recognized that an increase in the volatile acid concentration is one of the first signs of an upset digester and signals the need for control measures long before a drop in pH and a "stuck" digester result.

Although it is commonly agreed that a volatile acids buildup is the result of unbalanced digestion conditions, the actual effect of a high volatile acid concentration on the digestion process has been strongly debated. One group of investigators believes that high acid concentrations are the result of a low activity of the methane-producing organisms. They believe that volatile acids are toxic to these organisms only in an indirect manner through a reduction in pH, a condition which can be relieved by the addition of buffering materials such as lime. This view has recently been supported by the work of Cassell and Sawyer (1), Sawyer *et al.* (2), and Kaplovsky (3). The other group of investigators feels that a volatile acid concentration above about 2,000 mg/l causes a retardation of the methane-producers regardless of the pH maintained. Thus, they believe materials added to raise the pH are of no benefit and the toxic conditions can be relieved only through a reduction in the organic load or by dilution. This view was presented by Buswell *et al.* (4) and has been most recently supported by the work of Schulze and Raju (5) and Mueller *et al.* (6).

Each side has presented substantial evidence to support its claim, but there has never been a sufficiently extensive study conducted to resolve the problem. This is an important issue in digester control as only through a knowledge of the true effect of high volatile acid concentrations can effective and practical measures be applied to meet these conditions successfully and economically. This study was undertaken to determine the fundamental effect of volatile acids on methane formation in anaerobic digestion and to resolve the apparent difference in the theories of the previous investigators.

Theoretical Considerations

The anaerobic digestion process has been used most successfully in the past for the stabilization of sewage sludge. This sludge consists essentially of two portions, a solid portion composed of material settled in the clarification

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The paper was presented in full at the Annual Meeting, New York Sewage and Industrial Wastes Assn., New York, N. Y., Jan. 20–22, 1960.

This includes the portion on volatile acid toxicity and a later paper will discuss salt toxicity.

tanks, and a liquid portion containing materials actually in solution. The concentration of materials in true solution is relatively low in the raw sludge charged to the digester, essentially no higher than contained in the sewage entering the treatment plant. These dissolved materials are the only ones capable of affecting the microorganisms.

After the sludge is sent to the digestion tanks, the organic materials, contained mostly in the solid portion of the sludge, are slowly hydrolyzed and brought into solution by the bacteria and enzymes present in the digester. Under normal conditions of operation, the organic matter is then quickly broken down into volatile organic acids by a group of bacteria, commonly called the "acid formers," and then in turn decomposed rapidly into carbon dioxide and methane by a second group of bacteria commonly called the "methane formers." Because of this rapid decomposition, the quantity of organic matter actually in solution normally remains low. There is, however, a buildup of certain salts in solution such as ammonium, calcium, and magnesium bicarbonates resulting from the breakdown of proteins and soaps. In a digester these salts produce the natural buffers, which normally remain fairly constant at about 3,000 to 4,000 mg/l as calcium carbonate.

When unbalanced digestion conditions exist, the methane-producing organisms cannot remove the volatile acids as quickly as they are formed and consequently a buildup of the acids results in solution. This buildup can take place very rapidly, and in a day or two the total concentration of materials in solution can be more than doubled. To prevent a disastrous drop in pH from a large acid increase, alkaline materials such as lime or sodium hydroxide may be added for neutralization. These added materials also tend to greatly increase the concentration of materials in solution. The rapid increase in volatile acids and subsequent neutralization with alkalies are very similar to a large slug load of volatile acid salts to the digester and the effects produced will be identical to this condition.

Mueller *et al.* (6) and also Kaplovsky (3) (7) have demonstrated that under adverse conditions, the main volatile acids which build up in solution are acetic acid, propionic acid, and butyric acid. This indicates that the organisms responsible for the degradation of these compounds are perhaps the most sensitive to environmental change and so are largely responsible for digester upsets. It is the effect of high volatile acid concentrations on this particular group of methane formers which is of particular importance.

Experimental Procedure

This study was conducted by simulating the effect on the methane organisms of a rapid increase in the volatile acid, acetic acid, and subsequent neutralization with sodium hydroxide as might be performed in the field under adverse digestion conditions. This was done by adding high concentrations of the volatile acid salt, sodium acetate, on a slug basis to a series of digesters containing an active population of acetate-utilizing methane organisms and observing the effect of this addition on the rate of acetate utilization. For comparative purposes, slug loadings of other sodium salts—sodium chloride, sodium bicarbonate, and sodium sulfate—were also studied.

The digesters for slug feeding consisted of a series of one-liter bottles as illustrated in Figure 1. Each digester was connected to a gas collection tube containing an acidified saturated salt solution. Feedings to these digesters were made anaerobically through a tube at the top of the digester, using a pipette. The digesters were operated in a digestion room at a temperature of $35 \pm 0.5°C$. Digested sludge from the Nut Island primary treatment plant,

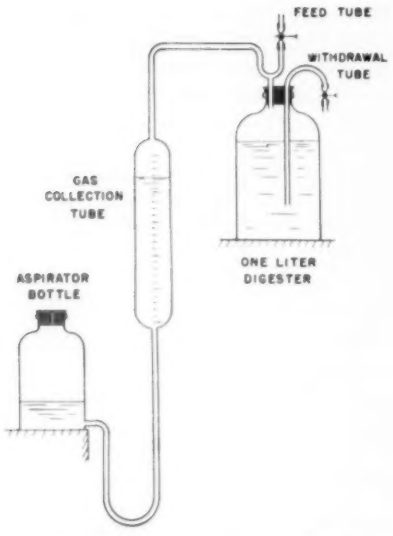

FIGURE 1.—Schematic diagram of batch-fed digester.

Boston, Massachusetts, was used for seed after suitable preparation and acclimation to an acetic acid substrate.

Preparation of the sewage sludge consisted of passing the sludge through a 16-mesh aluminum screen and diluting one part of the screened sludge to two parts of Cambridge tap water, thus making the sludge thin, uniform in composition, and low in initial salt concentration. A typical analysis of the sludge after this preparation is given in Table I. The buffering capacity, or ability of the sludge to resist a drop in pH, was then increased by the addition of sufficient sodium bicarbonate to increase the alkalinity to between 2,500 and 4,500 mg/l. This prepared sludge was then acclimated to 2 g/day/l of acetic acid in a 19-l digestion unit operated on a 30-day detention time and equipped for continuous feeding of the acetic acid and with gas recirculation for mixing as illustrated in Figure 2. During the acclimation period of about three weeks, the acetic acid concentration was slowly increased in the 633-ml daily feed until the acid was being utilized at a rate of 2 g/day/l for a period of at least 5 days. This rate was determined from gas production and volatile acids analyses.

Just prior to a slug feeding study, the empty one-liter digesters were purged to replace all the air with digestion gas from the acclimation digester. Three-fourths liter of the acclimated sludge was then transferred anaerobically to each digestion unit. Initial analyses for gas composition, pH, and volatile acid concentration were then made on samples drawn from each unit.

Slug feedings were then made, consisting of 100 ml of distilled water containing the desired salts, making a final total volume in each digester of 803 ml. Gas production was measured every 3 hr for the first 15 hr after feeding and as often after that as appeared necessary. All gas produced was analyzed for carbon dioxide and methane. At the end of each slug feeding study the sludge in each unit was analyzed for pH, volatile acids, alkalinity, organic and ammonia nitrogen, and total and volatile solids. These analyses were also performed on the acclimated sludge at time of transfer.

The rate of acetate utilization was based on gas production and analysis, and volatile acids analysis. Buswell (1) has shown that the decomposition of one mole of acetic acid results in the production of essentially one mole of carbon dioxide and one mole of methane as follows:

$$CH_3COOH \rightarrow CO_2 + CH_4 \ldots (1)$$

When sodium acetate is added, however, the sodium remaining from the

TABLE I.—Typical Analysis of Prepared Digested Sludge Seed

Item	Amount
Alkalinity (mg/l)	1,360
Total solids (per cent)	1.14
Volatile solids (per cent)	56.7
Organic nitrogen (mg/l)	452
Ammonia nitrogen (mg/l)	200

TABLE II.—Rate of Acetate Utilization and Sludge pH for Sodium Acetate Feed

Na Acetate Feed (mg/l as Acetic Acid)	Rate of Acetate Utilization (g/l/day)			Sludge pH	
	Initial	Maximum			
		Rate	Day	Initial	Final
2,000	2.90	2.90	1	7.40	7.85
4,000	2.30	2.30	1	7.50	8.05
7,000	0.53	0.70	3	7.50	8.20
10,000	0.30	0.54	6	7.50	8.15
12,000	0.15	0.34	7	7.50	8.05
16,000	0.13	0.19	12	7.50	7.86

decomposition of the acetate combines with water and the carbon dioxide produced to form sodium bicarbonate as follows:

$$CH_3COONa + H_2O \rightarrow CH_4 + NaHCO_3 \quad (2)$$

Thus, the decomposition of one mole of sodium acetate results essentially in the production of one mole of methane, or in other terms, the decomposition of 1 gram of acetate as acetic acid results in the production of 418 ml of methane gas at 35°C and standard pressure. It was found that the actual production of methane checked within a few per cent of this value. Identical slug feedings of acetate salts to six one-liter digesters indicated that the rates of acetate utilization based on gas production were reproducible within about two per cent. This procedure was followed throughout the study.

Results

Slug Feeding with Sodium Acetate

Six digesters were fed sodium acetate in concentrations from 2,000 to 16,000 mg/l as acetic acid to determine the effect of increasing concentrations of sodium acetate on its rate of decomposition. The acetic acid concentration in the acclimated sludge was almost 1,000 mg/l prior to feeding so the actual concentrations after feeding were about 1,000 mg/l higher than that fed. The results of the slug feeding, illustrated in Figure 3, show that as the concentration of acetate fed was increased above 2,000 mg/l, the rate of its utilization decreased. This decrease was noticeable with only 4,000 mg/l of acetate and was very marked

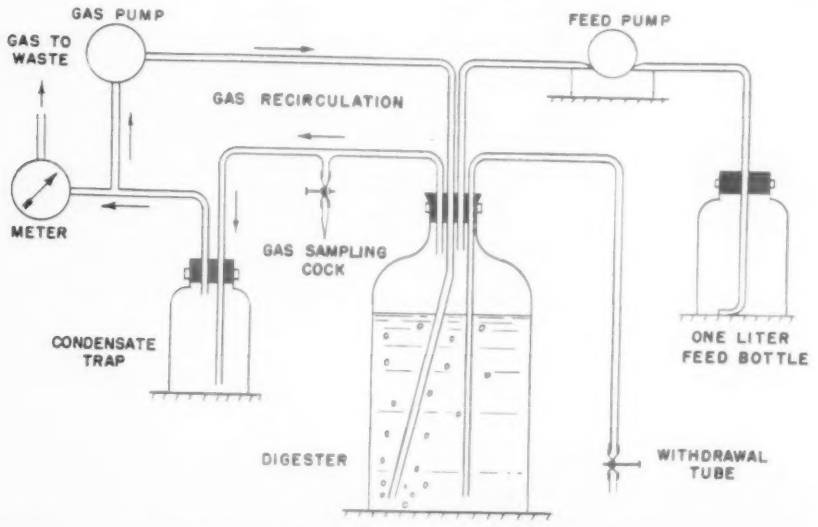

FIGURE 2.—Schematic diagram of continuous-fed digester.

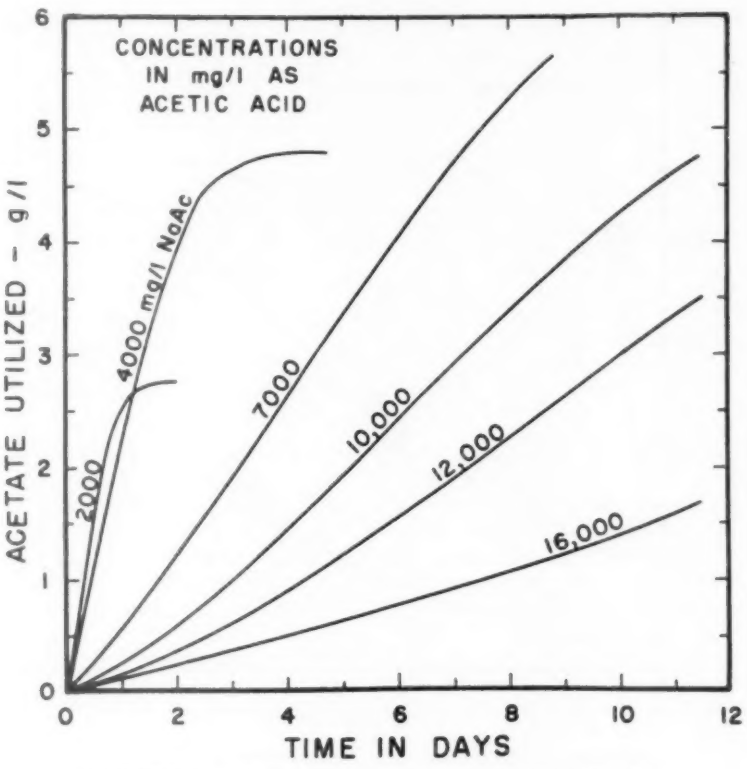

FIGURE 3.—Effect of sodium acetate on acetate utilization.

with 7,000 mg/l. A comparison of the initial and maximum rates of utilization listed in Table II indicated that with time a slight amount of acclimation to the toxic effect of high sodium acetate concentration took place.

The rapid decrease in rate of acetate utilization at the end of about 20 hr with 2,000 mg/l and after about 2 days with 4,000 mg/l of feed indicated the complete utilization of the acetate. The study was stopped at the end of the 12th day although utilization was still taking place in all systems with acetate concentrations above 4,000 mg/l. The pH during the run remained high in all units as shown in Table II and at the end of the run was greatest in the digesters with the most total acetate utilization and therefore with the highest sodium bicarbonate concentration. This run definitely indicated that a rapid increase in the concentration of volatile acids and subsequent neutralization with sodium hydroxide would hinder the methane-

TABLE III.—Sodium Chloride Feed; Rate of Acetate Utilization and Sludge pH

NaCl Added (mg/l)	Rate of Acetate Utilization (g/l/day)			Sludge pH	
	Initial	Maximum			
		Rate	Day	Initial	Final
0	1.95	1.95	1	7.25	7.65
4,860	0.68	0.80	2	7.30	7.70
7,800	0.28	0.36	3	7.30	7.70
9,750	0.16	0.27	6	7.30	7.70
13,600	0.08	0.27	10	7.30	7.90

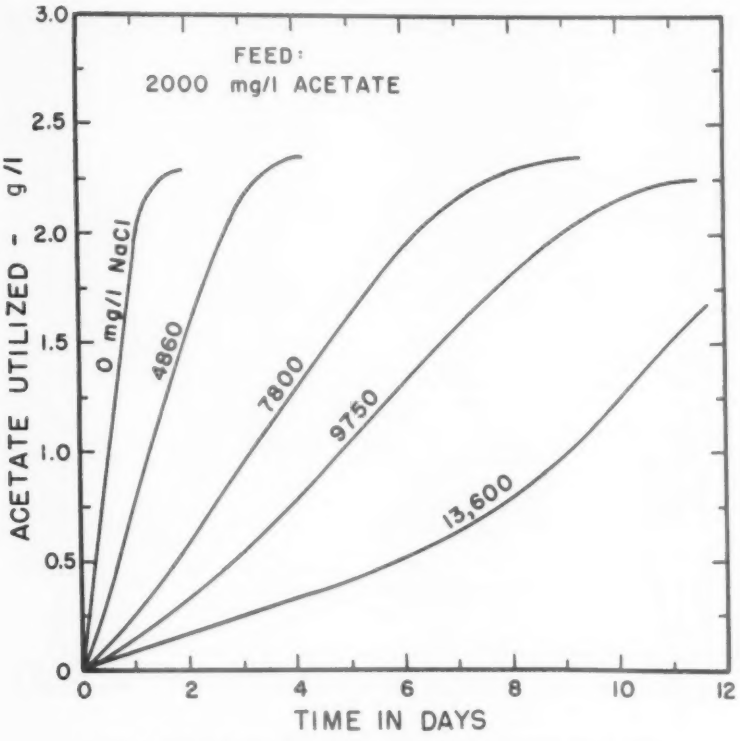

FIGURE 4.—Effect of sodium chloride on acetate utilization.

forming organisms. Whether this toxic effect was due to the volatile acid anion portion of the sodium acetate salt, or whether the sodium cation portion of the salt was mostly responsible, could not be determined from this study alone.

Slug Feeding with Sodium Chloride

This slug feeding was conducted to determine the effect of the neutral salt, sodium chloride, on the rate of acetate utilization. The substrate used in this study was 2,000 mg/l of sodium acetate. One digester served as a control and sodium chloride was added to four other units in increasing concentrations from 4,860 to 13,600 mg/l. The results of this study are shown graphically in Figure 4. Here again, as with slug feeding of sodium acetate, the rate of acetate utilization decreased markedly with increase in the salt concentration. Table III shows that there was some acclimation to the high salt concentration, especially in the systems fed 13,600 mg/l of salt. Thus, the effect of a slug feeding with sodium chloride was very similar to that obtained with sodium acetate.

Slug Feeding with Sodium Bicarbonate

In this run the effect of high concentrations of sodium bicarbonate on acetate utilization was studied. Bicarbonate forms the natural buffer in digesters, higher concentrations serving to maintain higher pH values and offering greater resistance to pH drop due to an increase in acid concentration. A substrate consisting of 2,000 mg/l of sodium acetate as acetic acid

was again used. The sodium bicarbonate was added on a slug basis to six digesters in concentrations ranging from 0 to 16,800 mg/l. The results of this run are shown in Figure 5. The results, again, were very similar to those obtained from feeding sodium acetate and sodium chloride. There was some acclimation in all units with sodium bicarbonate concentration greater than 2,620 mg/l except with the highest concentration of 16,800 mg/l as shown in Table IV.

TABLE IV.—Sodium Bicarbonate Feed; Rate of Acetate Utilization and Sludge pH

$NaHCO_3$ Added (mg/l)	Rate of Acetate Utilization (g/l/day)			Sludge pH	
	Initial	Maximum			
		Rate	Day	Initial	Final
0	2.00	2.00	1	7.30	7.80
4,580	0.84	0.92	1	7.30	7.85
6,550	0.36	0.56	2	7.30	7.90
10,500	0.16	0.30	4	7.35	8.00
13,100	0.13	0.17	6	7.30	8.00
16,800	0.12	0.12	1	7.35	8.05

Slug Feeding with Various Sodium Salts

The preceding three runs showed that although a high acetate concentration was detrimental to the methane-producing organisms even at pH values greater than 7.0, the same effect was also produced by two other common sodium salts. It was then desired to determine if this toxic action was perhaps largely due to the cation portion of the salt, rather than the anion portion. To study this, several different sodium salts were added to digesters, while maintaining the same sodium concentration in each digester. The salts used were sodium acetate, sodium chloride, sodium bicarbonate, and sodium sulfate. The substrate was 2,000 mg/l of sodium acetate as acetic acid.

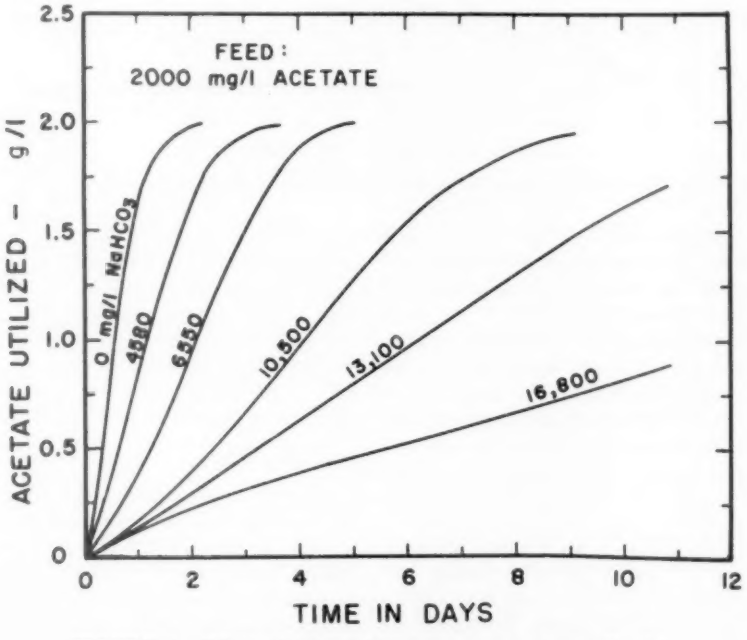

FIGURE 5.—Effect of sodium bicarbonate on acetate utilization.

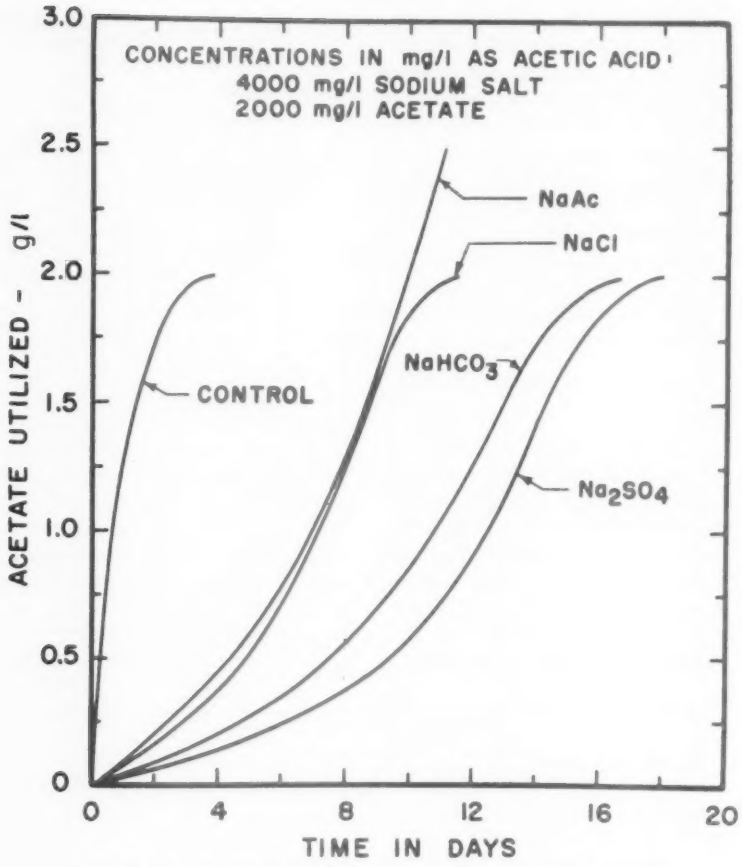

FIGURE 6.—Effect of various sodium salts on acetate utilization.

One digester served as a control and each salt was added in concentrations of 4,000 mg/l and 10,000 mg/l as acetic acid to different digesters.

The results of this run are shown in Figure 6. In all units fed 10,000 mg/l of the sodium salts, there was no acetate utilization, indicating the units had completely died from this high salt concentration. The data show that 4,000 mg/l of the various salts was quite toxic. Sodium acetate and sodium chloride were almost identical in toxicity, while the bicarbonate was somewhat more toxic, and the sulfate the most toxic. However, a comparison of the rates of acetate utilization given in Table V indicates that the relative toxic effects of the four salts compared with the rate of utilization in the control were very similar and there was very little difference in effect from the four different anions. The main toxic effect, therefore, appeared associated with the sodium cation.

Nitrogen Studies

Analyses were made of the sludge before and after slug feeding with the various salts to determine the changes which took place in the organic and ammonia nitrogen concentrations. If the added salts were non-toxic, the organisms would grow and multiply,

TABLE V.—Addition of 4,000 mg/l of Various Sodium Salts; Rate of Acetate Utilization and Sludge pH

Sodium Salt Added	Rate of Acetate Utilization (g/l/day)			Sludge pH	
	Initial	Maximum			
		Rate	Day	Initial	Final
Control	2.04	2.04	1	6.90	7.50
NaAc	0.10	0.52	11	6.90	8.10
NaCl	0.10	0.34	9	6.90	7.65
$NaHCO_3$	0.00	0.20	14	6.90	7.80
Na_2SO_4	0.00	0.28	14	6.90	7.60

taking in ammonia nitrogen and converting it into organic nitrogen in the form of cellular protoplasm. On the other hand, if the added salts were toxic, the organisms would die, and the organic nitrogen contained in the cell would be released to the system as ammonia nitrogen through cell lysis. Thus, an increase in organic nitrogen and decrease in ammonia nitrogen indicated bacterial synthesis and non-toxic conditions, while the opposite change indicated cell death and toxic conditions.

The changes in the nitrogen forms with the various slug additions of sodium chloride are listed in Table VI. Theoretically, a decrease in ammonia nitrogen concentration should be balanced by an equivalent increase in the organic nitrogen concentration. These data show this to be within experimental error. In general, the higher the salt concentration, the greater the death of the organisms as indicated by inceasing ammonia nitrogen and decreasing organic nitrogen concentration.

TABLE VI.—Changes in Nitrogen Forms From NaCl Additions

NaCl Added (mg/l)	Change in Nitrogen Forms	
	NH_4-N (mg/l)	Organic-N (mg/l)
0	−6	14
4,680	16	−15
7,800	12	−11
9,750	18	−15
13,600	23	−15

The similarity in the toxic effect of the four sodium salts added in a concentration of 4,000 mg/l as acetic acid is indicated by the nitrogen changes listed in Table VII. Here the changes in the nitrogen forms were very similar and indicative of strongly toxic conditions compared to the non-toxic conditions in the control.

TABLE VII.—Changes in Nitrogen Forms From Additions of 4,000 mg/l of Various Sodium Salts

Salt Added	Change in Nitrogen Forms	
	NH_4-N (mg/l)	Organic-N (mg/l)
Control	4	10
NaAc	38	−28
NaCl	30	−30
$NaHCO_3$	40	−44
Na_2SO_4	30	−32

Discussion of Results

Under normal conditions of digester operation, the concentration of materials actually in solution is relatively low. When unbalanced digestion conditions exist, the soluble organic material is not removed from solution as quickly as it is formed and a buildup of this material results, usually in the form of the low molecular weight fatty acids, or volatile acids. It is commonly believed by many that these volatile acids are toxic to the methane organisms in concentrations above 2,000 to 6,000 mg/l, independent of pH.

From this investigation a different theory of toxicity can be presented. The decreased activity of methane bacteria often observed following a rapid increase in volatile acids is not due to "volatile acid" toxicity, but is associated in a more general way with "salt" toxicity. This is an important differ-

ence as salt toxicity, which has been extensively studied in the biological field, is dependent mainly on the type and concentration of the cation of the volatile acid salt, while volatile acid toxicity is associated with the anion portion. Thus, based on the "salt" toxicity concept, relatively high volatile acid concentrations can be tolerated provided they are neutralized with alkaline materials containing a cation of low toxicity. This salt toxicity theory is supported by the fact that four different sodium salts, including sodium acetate, all exhibited essentially the same toxic effect at the same sodium concentration, relatively independent of the anion.

Based on this salt effect, the toxicity often found in digestion can be explained. Many different conditions can cause an unbalance between the acid-forming and the methane-forming populations, such as change in temperature, change in organic loading, or addition of some toxic substance. Under these unbalanced conditions, volatile acids may be produced faster than they can be destroyed, thus increasing their concentration in solution. If this increase exceeds the buffering capacity of the digester, the pH will drop and the hydrogen ion concentration will increase.

The hydrogen ion is known to be one of the most toxic cations to biological systems and can be removed by the addition of an alkaline material, which in effect replaces the hydrogen ion with another cation. If the cation used to replace the hydrogen ion is also toxic, however, then conditions will not be improved, even at the higher pH. This is essentially the condition which would result if sodium hydroxide was used for neutralizing the acids, since sodium is relatively toxic even at low concentrations when added on a slug basis.

Conclusions

1. The decreased activity of methane bacteria often observed following a rapid increase in volatile acid concentration and subsequent neutralization is not due to "volatile acid" toxicity, but is associated in a more general way with "salt" toxicity.

2. Salt toxicity is associated for the most part with the type and concentration of the cation portion of alkaline materials used for neutralization of the acids.

3. Sodium salts are relatively toxic to methane bacteria when added on a slug basis and therefore sodium hydroxide is a poor material to use for neutralization of excess volatile acids.

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BIOLOGICAL OXIDATION OF SEVERAL VINYL COMPOUNDS

Herbert R. Pahren and Don E. Bloodgood

The rapid growth of the organic chemical industry during recent years has resulted in a sharp increase in the quantity of synthetic organic chemicals present in many wastes and in receiving streams. Many of these synthetic chemicals, unknown outside the research laboratory a few years ago, now are widely used and distributed. Consequently, these chemicals enter the streams of the nation in one way or another and may be present at a point of downstream water use. Numerous organic substances are now being found in domestic water supplies.

Organic chemicals which are contained in industrial wastes discharged to streams may be classed into two general groups: (*a*) those rapidly destroyed in streams and (*b*) those which travel a long distance or persist almost indefinitely. Because biochemical oxidation may create serious problems in a stream, tests which assess biological oxygen requirements of the chemicals have a practical meaning for the first group. However, potential damage to a stream by chemicals of the second type cannot be determined by such analyses. In many important inland waters, progressive deterioration in the quality of water has occurred without serious oxygen depletion. A chemical pollutant which persists in a flowing stream is at least as important as one that undergoes rapid biochemical oxidation. The stream has little or no self-purification capacity to eliminate the resistant pollutants. With an easily oxidized pollutant, use can be made of the assimilative capacity of streams and these chemicals are generally of consequence only in terms of dissolved oxygen depletion.

There have been a number of reports concerning wastes containing organic compounds which are resistant to biological breakdown. However, there is a dearth of information on the possibility of vinyl monomers being resistant to biological oxidation if these compounds were discharged to a stream. Therefore, to assist in filling these gaps, it was decided to investigate the biochemical oxidation characteristics of several vinyl compounds to determine their behavior in dilute solutions.

Apparatus and Procedure

An experimental apparatus was constructed with which measurements could be made to determine the oxidation of the compounds to be studied. The apparatus, illustrated in Figure 1, was designed to supply carbon dioxide-free air to an oxidation chamber and to absorb any carbon dioxide in the air leaving the oxidation system. Any carbon dioxide in the air leaving the system was attributed to the breakdown of organic material contained in the oxidation chamber. The principles of this apparatus were not new, as similar systems were used in previous work by Porges *et al.* (1), and by Ludzack and Kinkead (2).

At the time this paper was prepared, Herbert Pahren was a graduate student at Purdue University, Lafayette, Ind. He now is with the U. S. Public Health Service in Denver, Colo. Don Bloodgood is Professor of Sanitary Engineering at Purdue.

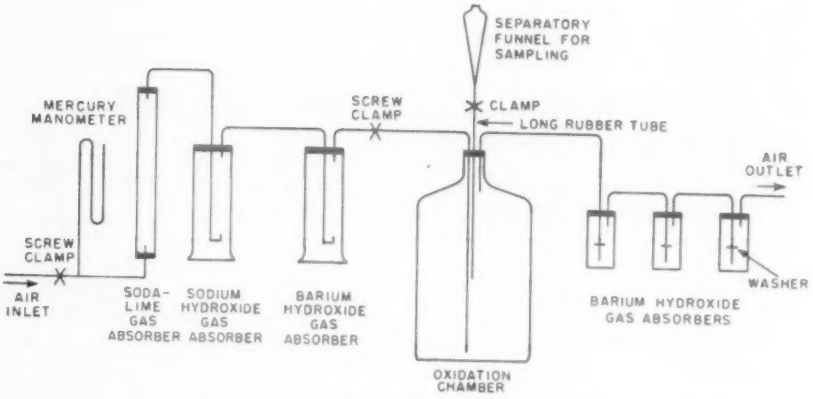

FIGURE 1.—Laboratory oxidation apparatus.

Compressed air entered the carbon dioxide absorption section of the apparatus and was adjusted for proper flow rate by means of a screw clamp, before passing through a tube containing soda-lime where the carbon dioxide was removed from the air. A mercury manometer was attached to the air inlet line prior to the soda-lime tube in order to show any erratic pressure changes in the system. The air leaving the soda-lime tube was next passed through two gas absorption bottles in series. The first bottle contained a 25-per cent sodium hydroxide solution which scrubbed out from the air any carbon dioxide not removed in the soda-lime tube. The second gas absorption bottle contained approximately 50 g/l barium hydroxide solution. The barium hydroxide acted as an indicator of any carbon dioxide in the air leaving the absorber which contained sodium hydroxide. Any CO_2 entering the barium hydroxide scrubber would be converted to barium carbonate, a white precipitate. The presence of this white precipitate would indicate the need for changing the chemicals in the carbon dioxide absorption section.

Air leaving the initial carbon dioxide absorption section of the apparatus was split into three equal portions, with each portion going to a five-gallon carboy. Air flow rate to each carboy was adjusted to about one bubble per second by means of a screw clamp on the line leading to the carboy. Air entered the bottle through a glass tube extending to the bottom and was removed near the top. All three carboys contained 16 l of seeded BOD dilution water. However, two of the carboys also contained a vinyl compound. The third chamber was used as a control. A separatory funnel was connected to each oxidation bottle and was used to siphon out a sample of the solution when necessary without breaking the seal on the system. The separatory funnel was held lower than the liquid level of the bottle and the siphoning action was started with a rubber suction bulb.

The air leaving each of the carboys was passed through a separate carbon dioxide absorption system. Each system consisted of three small bottles in series with 50 ml of barium hydroxide solution in every bottle. A rubber washer was fitted on the glass inlet tube in each of the bottles in order to force the bubbles to travel around the washer and hence effect maximum retention of the air bubbles rising to the surface of the solution.

At the beginning of each test run, fresh barium hydroxide was added to

all three absorption bottles. At the same time, 50 ml of the barium hydroxide solution was separately titrated with a standardized hydrochloric acid solution to determine the initial strength. On each subsequent day, the first bottle of the three in series was titrated with the acid. The reduction in barium hydroxide strength could then be related to the carbon dioxide absorbed. Carbon dioxide attributed to the test chemical was determined by subtracting any CO_2 produced by the control from that obtained from the carboy containing the chemical.

Only the first of the three bottles was removed each day for titration as almost all of the carbon dioxide was removed in this bottle. After the titration, fresh barium hydroxide was added and the bottle was placed in the third position of the series while the other two bottles were moved up one position. Each time a bottle was refilled with the alkaline solution, a separate 50-ml portion of the same solution was titrated so that the initial strength would be known.

Compounds to be tested were mixed with standard BOD dilution water and, when desired, a settled domestic sewage seed. The studies were carried out at 80°F in a dark room. The absence of light prevented any growth of algae which could interfere with the tests.

Experimental Results

Five vinyl compounds were used to determine whether typical vinyl monomers would be completely oxidized biologically under aerobic conditions. Information could be obtained on the complete oxidation of the chemical since the carbon dioxide measured is an end product of oxidation. Compounds tested included acrylic acid, methacrylic acid, vinyl acetate, methyl methacrylate, styrene, and dextrose. In all cases the concentration of chemical used was approximately 10 mg/l.

Initially, a dextrose solution was tested in order to obtain information on the oxidation characteristics of a compound known to be easily oxidized. During a 36-day period, 83 per cent of the total theoretical carbon dioxide was recovered. The carbon dioxide not recovered was attributed to the use of the carbon for the formation of bacterial cell protoplasm in the solution.

Three runs were made with solutions containing acrylic acid. The first two runs were seeded with sewage. When the carbon dioxide production from the second test decreased to a relatively low value, additional acrylic acid was added to the carboy and this constituted the third run. No additional seed was added to the third oxidation unit, as the acclimatized bacterial population remaining from the second run was considered adequate. Similarly, studies were made with methacrylic acid, vinyl acetate, and methyl methacrylate. Generally, carbon dioxide production began on the first or second day. The CO_2 production rate reached a peak between the third and fifth day and then gradually diminished. When methyl methacrylate was seeded with sewage, a lag was experienced as no carbon dioxide was formed until the third or fourth day. This lag was not apparent when additional methyl methacrylate was added to a solution that had been in the oxidation unit for 19 days. Acclimatized organisms were, no doubt, present in the latter case. Results of the carbon dioxide production for all test runs are included in Table I.

Styrene behaved quite differently from the other vinyl compounds tested. Unlike the other compounds which dissolved fairly rapidly, styrene formed a film on the surface of the solution and very little seemed to dissolve. Much of the styrene apparently volatilized while the solution was being mixed. Only about 10 per cent of the theoretical CO_2 was recovered during the test period. In an effort to determine the effects of mixing on the styrene,

TABLE I.—Summary of Experimental Results

Material Tested	Seed	Test Duration (days)	CO_2 Production (% of theoretical)
Dextrose	Sewage	36	83
Acrylic acid, Run 1	Sewage	42	71
Run 2	Sewage	19	70
Run 3	Acclimatized	22	81
Methacrylic acid, Run 1	Sewage	42	86
Run 2	Sewage	19	68
Run 3	Acclimatized	22	87
Vinyl acetate, Run 1	Sewage	38	49
Run 2	Sewage	19	27
Run 3	Acclimatized	22	58
Methyl methacrylate, Run 1	Sewage	33	44
Run 2	Sewage	19	42
Run 3	Acclimatized	22	66
Styrene, Run 1	Sewage	36	10
Run 2	Sewage	36	12
Run 3	Sewage	36	11
Run 4	Sewage	17	6
Run 5	Sewage	17	23

Runs 4 and 5 were made. With Run 4, the solution was agitated violently after the styrene was added while the solution was gently swirled for Run 5. As shown in Table I, recovery of CO_2 in Run 4 was only 6 per cent, while 23 per cent was recovered in Run 5.

Infrared analyses were made of the sample extracts after several weeks of oxidation, for one run of each of the five vinyl compounds. In all cases the infrared curves appeared characteristic of metabolic or cell materials. Original feed materials or their immediate derivatives were not detectable.

Discussion

None of the five vinyl compounds tested appeared to be completely resistant to biological oxidation. Carbon dioxide, the complete oxidation end product, was obtained in varying quantities from oxidation systems containing each of these monomers.

If any of the compounds studied were contained in an industrial waste

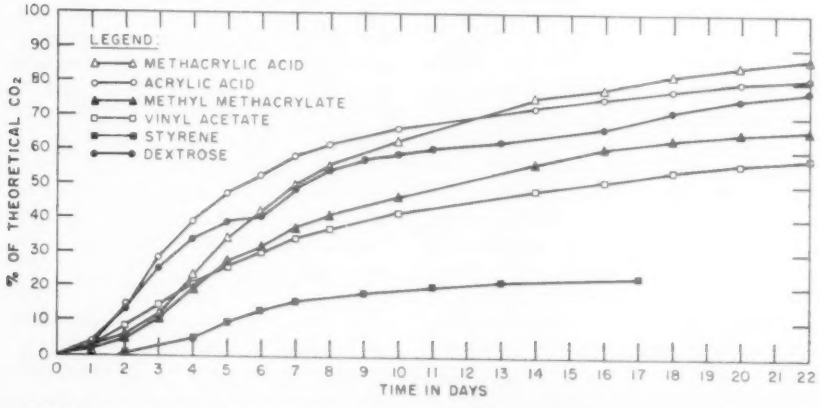

FIGURE 2.—Per cent of theoretical recovery of CO_2 vs. time for compounds tested.

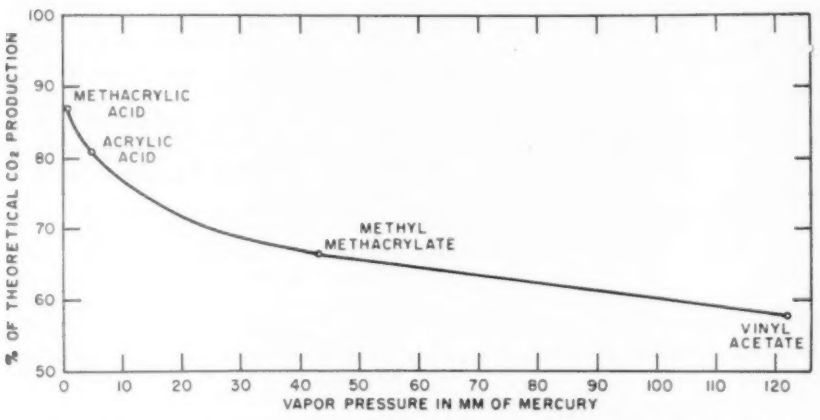

FIGURE 3.—Per cent of theoretical CO_2 recovery vs. vapor pressure of vinyl compounds at 80°F.

and continuously discharged to a stream, it is expected that microorganisms which are acclimatized to the compound would be present in the waters downstream from this industry. Therefore, a comparison was made of the results for the runs with acrylic acid, methacrylic acid, vinyl acetate, and methyl methacrylate when an acclimatized seed was present at the start. The dextrose test and the fifth run of the styrene studies, where an attempt was made to minimize initial volatilization, were included for comparison. This comparison is illustrated in Figure 2.

Since a portion of the styrene was insoluble in the dilution water and floated on the water surface, it was believed that this insoluble styrene volatilized and was carried off by the air passing through the oxidation unit before the chemical had a chance to oxidize. The cumulative per cent of theoretical carbon dioxide for the styrene was relatively small since the CO_2 produced during the run probably resulted only from the material in solution while the theoretical carbon dioxide was based on the total styrene used.

The per cent of theoretical carbon dioxide obtained, during the run with the initial acclimatized seed, for methacrylic acid, acrylic acid, methyl methacrylate, and vinyl acetate, was compared with the vapor pressure of each of these compounds at the operating temperature of 80°F. This information is illustrated in Figure 3.

The data show that lower carbon dioxide yields were obtained as the vapor pressure of the compound tested increased. This is in agreement with the theory that soluble materials volatilize more readily as the vapor pressure increases, and tends to confirm the belief that part of the unaccounted for vinyl compounds volatilized during the runs.

Consumption of barium hydroxide in the absorbers due to volatilized vinyl acids was considered. However, any volatilization of acid that may have taken place was probably very small, otherwise the equivalent carbon dioxide production would have been much less than that actually obtained.

Conclusions

1. An available apparatus can be used which is capable of determining the carbon dioxide resulting from the

biological oxidation of organic compounds.

2. In the biological oxidation of dextrose, styrene, acrylic acid, methacrylic acid, vinyl acetate, or methyl methacrylate, it appears that a part of the compound tested is used to form cell protoplasm.

3. Acrylic acid and methacrylic acid are as easily oxidized biologically as dextrose.

4. It is necessary to develop an acclimatized seed before the biological oxidation of methyl methacrylate will take place.

5. The carbon dioxide production from the biological oxidation of acrylic acid, methacrylic acid, vinyl acetate, and methyl methacrylate partially depends on the vapor pressure of the compounds. As the vapor pressure of the soluble compounds increases, there is more of a tendency for volatilization with the result that a smaller amount of the compound is available for biological oxidation.

6. Styrene is partially insoluble at a concentration of 10 mg/l. The insoluble styrene film which is formed on a water surface tends to volatilize rapidly with the result that this portion of the styrene is not available for biological oxidation.

7. After several weeks in the oxidaton apparatus, a portion of the acrylic acid, methacrylic acid, vinyl acetate, methyl methacrylate, and styrene is oxidized to carbon dioxide and all of the remaining chemical is believed to be either volatilized or converted into cell protoplasm.

8. Infrared analyses of samples of acrylic acid, methacrylic acid, vinyl acetate, methyl methacrylate, and styrene solutions after several weeks in the oxidation apparatus revealed no identifiable intermediate oxidation products.

Acknowledgment

Appreciation is extended to F. J. Ludzack of the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, for performing infrared analyses on several samples and interpreting the results.

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2. Ludzack, F. L., and Kinkead, D., "Persistence of Oily Wastes in Polluted Water Under Aerobic Conditions." *Ind. Eng. Chem.*, **48**, 2, 263 (1956).

MEETINGS OF INTEREST

Mar. 21–30	**American Chemical Society,** St. Louis, Mo. American Chemical Society, 1155 16th St., N. W., Washington 6, D. C.
Mar. 30–31	**Industrial Water and Waste Conference,** Rice University, Houston, Tex. J. P. Wold, P.O. Box 2633, Houston, Tex.; or Professor A. W. Busch, Rice University, Houston, Tex.
Apr. 5–7	**Sewage Works Short Course,** South Dakota State College, Brookings, S. Dak.
Apr. 6–7	**Tenth Southern Municipal and Industrial Waste Conference,** Duke University, Durham, N. C. Professor Edward H. Bryan, Dept. of Civil Engineering, Duke University, Durham, N. C.
Apr. 10–14	**American Society of Civil Engineers,** Hotel Westward Ho, Phoenix, Ariz. W. H. Wisely, ASCE, 33 West 39th St., New York 18.

ALGAE AS A SOURCE OF OXYGEN IN WASTE TREATMENT

A. F. Bartsch

As far back as human history goes, microscopic algae have served mankind by their ability to capture solar energy through photosynthesis and send it along varied pathways and through several trophic levels to a valuable terminus as consumable aquatic products. Algae have functioned largely unnoticed in the total scheme of organic decomposition in surface water. Only recently has there been much inquiry about how microscopic algae can be put to use for the greater benefit of mankind in waste treatment and other ways. Although familiar as laboratory subjects for photosynthesis and other plant physiological studies, algae have received intense and serious study largely since the start of World War II. Studies have been pointed toward growing them as a harvestable crop, making better use of them in waste treatment, and—more recently—providing food and acceptable environment for the astronaut of the near future.

Recent studies of stabilization ponds for treating municipal sewage and some industrial wastes have improved the understanding of where and how algae fit into the treatment process. Such studies, coupled with basic knowledge originating in a broader investigative program on algae, form the background against which algae can now be viewed as a source of oxygen in waste treatment.

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The paper was presented at the 137th Meeting of the American Chemical Society in Cleveland, Ohio, Apr. 5–14, 1960.

Trickling Filters

Algae normally present in trickling filter growth are shown in cross section in Figure 1. They are responsible for the dark green color seen on the upper stones during much of the year. Although the organism population may vary in detail from one filter to another, in the grosser aspects it is consistent, regardless of geography (1). The luxuriant algal population is an obvious indication that the environment is favorable and fosters algal growth. While this is to be expected in view of feed composition, it is natural to wonder about the contribution such algae make to waste stabilization.

Some algae are able to use organic substances directly for energy and growth and join other organisms in digestion and oxidation processes (2). Whether this accomplishment is substantial in relation to similar activities of the other biota is not known. More commonly considered is the by-product oxygen from algal processes and the uses to which it can be put in waste treatment.

Nevertheless, the available literature sheds little light on the oxygenating abilities of algae in the trickling filter, thus implying that it is insignificant. Records of diurnal variation in filter performance are scanty, but it is doubtful if they would reflect algal effect distinguishable from variations in sewage strength and volume. It is pos-

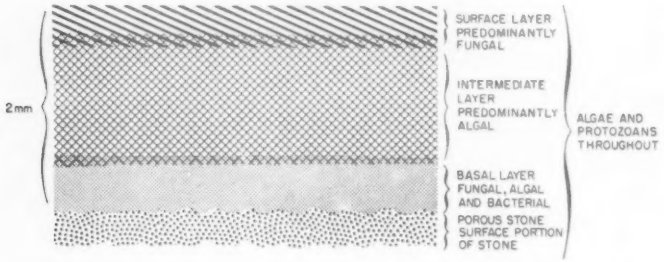
2mm
SURFACE LAYER PREDOMINANTLY FUNGAL
INTERMEDIATE LAYER PREDOMINANTLY ALGAL
BASAL LAYER FUNGAL, ALGAL AND BACTERIAL
POROUS STONE SURFACE PORTION OF STONE
ALGAE AND PROTOZOANS THROUGHOUT

FIGURE 1.—Cross section of growth on stone in a trickling filter (From Cooke and Hirsch—Ref. 4).

sible, however, to estimate crudely the daily oxygen production by algae. In recent studies of trickling filter populations by Cooke (3) and Cooke and Hirsch (4), algal density is given as number of cells or cell clumps per unit area of growth on glass sampling slides. Density varies appreciably at different times of year, but values of 20 million cells or cell clumps per square centimeter for high-rate filters and 5 million for standard-rate filters are frequent. If the effective diameter of cells and cell clumps is 30μ, 20 million/sq cm would have a volume of 0.282 cc. On this basis, there would be 5.58×10^6 cc of cell material on a 165-ft diameter filter such as that at Dayton, Ohio. It is also assumed that crevices and irregularities of the surface media increase by 50 per cent the illuminated filter area coated with algae. Thus, the inhabited area of the filter would support a total algal cell volume of 8.37×10^6 cc.

Ryther (5), Ryther and Yentsch (6), and Verduin (7) reported on observed rates of photosynthesis in algae and other plants under optimal, near-natural conditions. The value used here as a crude approximation is 0.5μ mole O_2 evolved per microliter of algae per hour at optimal light (7). At this rate, 8.37×10^3 liters of cell material would yield about 133.9×10^3 g O_2/hr (or about 294 lb/hr) at maximum rate. Based on the data of Ryther (8) and McConnell and Sigler (9) it is assumed that the average rate over the 12 daylight hours is in the neighborhood of 50 per cent of maximum, giving a gross yield of 1,764 lb/day of O_2. Also, from Krauss (10) and Ryther (11) algal respiration is assumed to take about 5 to 10 per cent of production so as to provide a net yield of 1,588 to 1,676 lb oxygen.

The Dayton sewage treatment plant has 20 trickling filters. The one sampled receives a daily load of 75,060 lb 5-day, 20°C BOD and decreases this amount by 63,248 lb. This requires 63,248 lb oxygen from all sources if the filter is to remain aerobic. If one-half the load were to be applied during the 12 daylight hours when algae are illuminated, oxygen from this source would equal only 5 per cent or less of the need.

Properly functioning filters that are covered with sunshading materials, and others that seem to lack an appreciable algal population, suggest that oxygen produced by algae not only is not required but has little value. It even seems likely that under present filter design much of such oxygen escapes to the atmosphere and contributes little to the filter function. Even so, there is a temptation to wonder whether a potentially valuable oxygen resource might not be developed and used to advantage through appropriate design modification.

Waste Stabilization Ponds

There is general agreement that algae are a valuable, necessary, and perhaps principal source of oxygen in waste stabilization ponds. Successful pond operation depends on bacterial decomposition of waste organics, occurring principally under aerobic conditions, dependent on oxygen produced by algae that utilize some of the decomposition products. At waste loadings generally used, oxygen of algal origin is necessary if aerobic processes are to be preserved even during daylight hours.

Involvement of algae in pond treatment of sewage stems from their spontaneous appearance a few days after a new facility is placed in operation. As the algae grow, they produce a population many times more dense than those found in natural, unenriched waters and in trickling filters. The algae are strikingly similar in stabilization ponds, wherever they may be (12), and attempts to influence the species characteristics of the population through inoculation or in other ways are not appreciably effective.

In addition to the limited direct utilization of organic matter by algae, their ability to yield oxygen at a rate of about 1.6 lb/lb of algae grown is their principal value. To obtain large quantities of oxygen, it is necessary to produce large quantities of algae. Experimental studies by Gotaas *et al.* (13) show that algal yields in sewage on an acre basis can be very high as compared with crops grown on agricultural land. At detention periods of one to two days, for example, yields were obtained of 22.5 to 35.6 tons/yr/acre at depths ranging from 2 to 12 in.

If harvesting a crop of algae is contemplated as a terminal step in the waste treatment process, the more algae produced, the better. On the other hand, if the algae are not to be reclaimed but will leave the pond environment as a component of the effluent, provision of photosynthetic oxygen entails some notable disadvantages. In either case, in the interest of getting all the oxygen needed, producing as much algae as possible often becomes an urgent goal. It appears necessary to resolve how this can be accomplished to outline the factors that influence algal photosynthesis.

The success of algae in a pond depends on an interacting complex of environmental conditions. Algal growth will be limited by whatever nutrient is present in minimum quantity, or by any physical conditions that are less than optimal. Increasing the suitability of one limiting factor in a combination soon makes another factor the limiting one, whether solar energy, density of algae, nutrients, or temperature.

Light

Under natural conditions the energy that drives the photosynthetic mechanism is solar radiation absorbed by the photosensitive green pigment, chlorophyll. Important considerations of light are quality, intensity, and duration. At present, there is no general agreement concerning the fine details of energy use, but Krauss (10) reported 20- to 25-per cent efficiency in long-term experiments with solar radiation. This is the most conservative and useful estimate now available. Laboratory and pilot-scale experiments by Oswald *et al.* (14) with *Chlorella* and *Scenedesmus* grown in sewage showed an energy use of 3.68 cal/mg oxygen evolved. Further studies indicated an energy conversion seldom exceeding 10 to 12 per cent of available light energy.

It is obvious that oxygen yield might be increased if a greater intensity of light were available. Within limits, photosynthetic rate is directly proportional to the intensity of the light. Phillips and Myers (15) reported that at about 24 ft-c the rate of oxygen production in *Chlorella* is equal only to

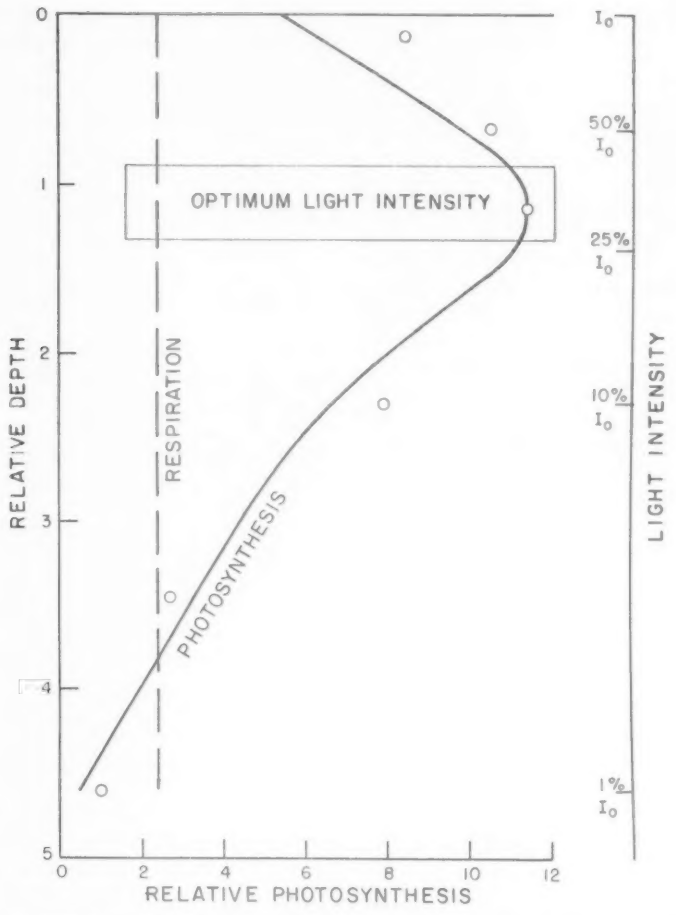

FIGURE 2.—Relative photosynthesis from surface to depth of penetration of one per cent of surface light (From Ryther—Ref. 8).

the rate of oxygen use. As intensity increases, photosynthesis increases proportionately until the saturation point is reached at about 400 to 600 ft-c. Beyond this point the rate remains constant until such high light intensities are reached that they inhibit photosynthesis. Such inhibition can be expected somewhere between 1,000 and 4,000 ft-c.

Of the sunlight that falls on the surface of a stabilization pond, part is reflected away and does not enter the water. Principally because of algae and other particulate matter, light that enters is absorbed rapidly and does not penetrate to depths as great as those noted for most bodies of water. Bartsch and Allum (16) reported that in Dakota waste stabilization ponds, 99 per cent of the light was absorbed in the upper 50 to 70 cm (Table I). Within this layer, oxygen production by algae can be expected to equal or exceed their consumption of oxygen. Light and dark bottle tests showed that,

at the depth where 0.5 per cent of surface light intensity occurred, oxygen production was insufficient to meet the respiratory demand of the total biological system.

Because of the pattern of light extinction in a stabilization pond, the pond content can be viewed as a vertical column consisting of three layers. In the upper layer, where the light intensity exceeds about 600 ft-c, there is more energy than the algal population can use effectively. In a shallow layer only about 10 cm thick, light is near optimum. This layer may occur at greater or lesser depths as sunshine increases or decreases. Often algae will concentrate in this layer, but circulation by wind and convection currents usually moves the algae at intervals into and out of the light. At increasing depths, photosynthesis decreases logarithmically along with further extinction of light. These relationships are shown diagrammatically in Figure 2, which is modified from one used by Ryther (8) to show similar conditions in the ocean.

Algal Density

The amount of algae grown in a stabilization pond is important for several reasons. With a yield of about 1.6 lb of oxygen for each pound of algae grown, the standing crop is indicative of past accomplishment in providing oxygen. Density of the population also determines the total amount of chlorophyll present which, because of its great affinity for light, serves as the principal screen in absorbing light entering at the water surface. Stabilization ponds have chlorophyll concentrations far exceeding those of more typical surface waters that have been studied. Data for some of them are shown in Table II taken in part from Ryther and Yentsch (6). Because of this, they are able to concentrate in a very shallow, economically provided layer, the same photosynthetic activity that would require a depth of up to several hundred feet in the ocean.

TABLE I.—Approximate Depth in Centimeters at Which Indicated Light Remains in Dakota Bodies of Water (Summer 1955)

Stabilization Pond or Other Body of Water as Indicated	10 per cent of Surface Light	1 per cent of Surface Light	Extinction Coefficient*
Kadoka, S. Dak.	14.0	40.6	9.6
Wall, S. Dak.	17.8	41.9	10.7
Lemmon, S. Dak.	33.0	69.9	5.9
Maddock, N. Dak.	25.4	58.4	7.0
Wishek, N. Dak.	16.5	39.4	10.8
Kadoka, S. Dak., Pothole	—	—	2.55
Murdo Lake, S. Dak.	4,013	7,162	0.58

* Extinction coefficient = k in equation $I/I_o = e^{-kl}$ with l expressed in meters.

TABLE II.—Chlorophyll "A" Concentrations

Source	Concentration (mg/l)
Five Dakota stabilization ponds	0.08 to 7.32
Stabilization ponds (Lebanon, Ohio, 1960)	0.184 to 0.328
Murdo Lake, S. Dak.	0.0004 to 0.0002
N.W. Atlantic Ocean*	0.001 to 0.002
East Sound, Wash.*	0.015 to —
Woods Hole Harbor*	0.00169 to 0.00335

* Data from Ryther and Yentsch (6).

Although chlorophyll is not an infallible indicator of photosynthesis, it is possible to use this value to estimate the approximate oxygen yield to be expected. Using a value of 0.22μ mole O_2 evolved/hr/μg chlorophyll under optimal light reported by Verduin (7), the estimated oxygen production rate for a stabilization pond at Lemmon, South Dakota, with 0.46 mg/l chlorophyll is 3.2 mg/l/hr. This compares favorably with a measured light and dark bottle rate of 2.9 mg/l/hr. Similar agreement of calculated and measured rates of production have been obtained for marine areas by Ryther and Yentsch (6) where the rate of production per volume is many times less.

Temperature

Stabilization ponds are scattered in all climatic areas of the country and are subjected to a wide annual range of temperatures. In the northern plains region, seasonal pond temperatures range from 0°C to 33°C. The full influence of temperature on stabilization pond algae is not known. Growth of *Chlorella*, and perhaps of many other algae, usually reaches a maximum between 25°C and 30°C, a commonly prevailing open water temperature in ponds. Strains of *Chlorella* that fare exceptionally well at 39°C have been reported by Burlew (17). They have also been studied by Burk *et al.* (18).

Apart from the influence of temperature on photosynthesis and growth, there are important indirect effects also. Decreasing temperature slows down the rate of biochemical degradation of organic matter, with the result that decomposition products suitable as algal nutrients are less abundant. Concurrently, the whole complex of approaching winter conditions commonly induces a thinning out of the algal population in the pond fluid. In part, this results from die-off of some algae, but many others seem to settle alive but dormant on the bottom. In this condition they not only are not effectively producing oxygen but are exerting a demand for the needs of respiration and algal decay.

In areas where appreciable ice cover occurs, the prospect of effective photosynthesis is unfavorable. In seven ponds studied, ice cover ranged from 26 to 66 cm thick (16). Such ice commonly was capable of reducing the surface light from an initial level of about 1,400 ft-c to a value of about 28 ft-c, less than the intensity at which oxygen production meets respiratory use. Then the non-functional algae become an oxygen-hungry liability, and anaerobic conditions frequently prevail under ice. Where thick ice cover is of long duration, aerobic conditions cannot be preserved even by reducing the rate of waste loading.

TABLE III.—Selected Algal Nutrients in Sewage*

Nutrient	Concentration (mg/l)
Nitrogen	20– 50
NH_3	7– 40
NO_2	0– 4
NO_3	0– 0.3
Organic	3– 42
Carbon	66–176
Soluble phosphorus	1– 13
Potassium	13– 44

* From Fitzgerald and Rohlich—Ref. 19.

Nutrients

Sewage contains appreciable amounts of the nutrients necessary for growth of dense populations of algae (Table III). Especially noteworthy are nitrogenous compounds, carbon, phosphorus, and potassium. Through the activities of the algae, the nutrients are removed from solution and concentrated in the algal cells. Fitzgerald and Rohlich (19) stated that ammonia nitrogen may be reduced up to 90 per cent; phosphorus, 96 per cent; and potassium, to 20 per cent, leaving the pond as components of algae in the effluent. When the nutrient levels have been reduced to a point where scarcity of one element becomes limiting, the rate of growth is decreased drastically. Because of its limited occurrence in sewage, carbon has been identified as the element most apt to function in this way.

On several occasions in South Dakota ponds at Lemmon and Kadoka the rate of photosynthesis at midmorning, as determined by light and dark bottles using pond samples, was about 50 per cent greater than at midday, in spite of the increasing light intensity. Although several factors may be jointly responsible, rapid depletion of available CO_2 from the level accumulated during nighttime decomposition appeared the most likely cause. From

studies with *Euglena* by Gotaas *et al.* (20) which could produce a yield of 1,550 lb dry algae per million gallons of sewage per day, it was estimated that if sufficient carbon were supplied to permit complete use of the available nitrogen, a yield of 3,300 lb would be possible. In any event, yield of algae per unit area can be increased by using higher waste loadings until impaired light penetration becomes a limiting factor.

Enhancement of Oxygen Production

Two philosophies emerge on the question of enhancing oxygen production by algae. One seeks to correlate in pond design the interrelated factors of depth, detention period, available solar radiation, and BOD loading so as to attain a maximum level of treatment efficiency. It has already been shown by Oswald *et al.* (14) that high efficiency in light energy utilization can be attained at detention periods of three to five days with BOD loadings of 225 lb/day/acre or more. Attaining such efficiency may be especially advantageous where harvesting of algae is contemplated, where land is expensive, and where close, competent pond supervision is possible. The other philosophy sees great advantage in the simplicity and dependability of ponds with low BOD loadings of 20 to 50 lb/day/acre and long detention time of 100 days or more where this is possible because land values are relatively low.

Although enhancing oxygen production to some high level may not be advantageous under all circumstances, a number of approaches suggest themselves. One obvious possibility is to grow more algae to make more oxygen, and this can be influenced by increasing nutrient availability through heavier waste loadings. Either cropping the algae in some way or shortening the detention time to some appropriate value in reference to the reproduction time of the algae should keep them in a vigorous growth phase with active chlorophyll.

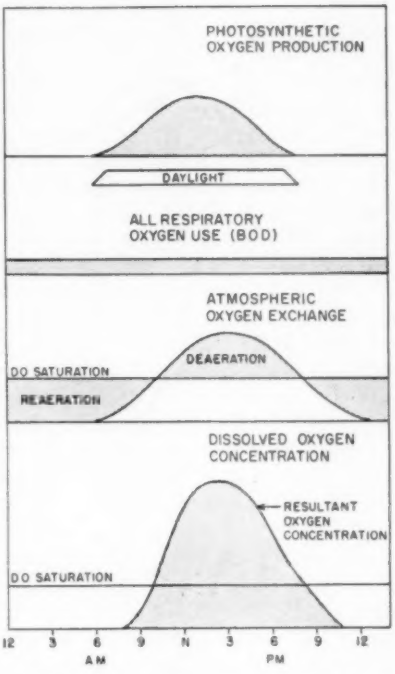

FIGURE 3.—Schematic diagram of the dynamics of dissolved oxygen gain and loss in a stabilization pond (From Odum—Ref. 21).

Another approach is to adjust depth in relation to both density of the algal population and to solar radiation so that extinction of light is complete at or just above the pond bottom. If such adjustment could be made, all of the light energy would be put to the photosynthetic task of producing oxygen at a rate of about 3.7 cal/mg. However, attempting to maintain control as delicate as this in the face of fluctuating light and algal density would require such constant attention by costly skilled technicians as to make the approach impractical.

Induced vertical circulation may benefit oxygen production by moving algal cells alternately into bright sunlight near the surface and into dark-

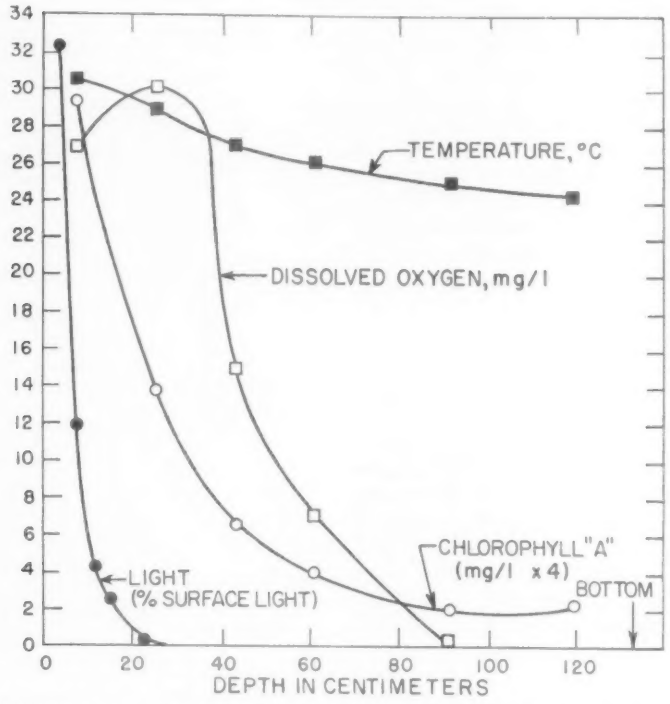

FIGURE 4.—Vertical variations in water quality in a stabilization pond (From Bartsch and Allum—Ref. 16).

ness near the bottom. It has been known for some time that light is not required continuously but only for initial activation or excitation of the photosynthetic process (10). Studies of *Chlorella pyrenoidosa* showed the dark time should be ten times the flash time for efficient use of light (17). Under idealized conditions of high turbulence at full sunshine, increase in oxygen evolution is calculated to reach sevenfold. To some extent, such circulation occurs naturally if the pond is sufficiently large and exposed to frequent winds. Where necessary, circulation could be induced mechanically by pumping. The value of mechanical agitation is yet to be demonstrated, but presumably the gain would be very much less than sevenfold.

Use of electric lighting has been suggested for continuing photosynthesis during the night. From preliminary examination of the costs involved, it seems likely that the attractive economy and simplicity of the stabilization pond would be lost.

Enhancement of Oxygen Utilization

Oxygen levels in stabilization ponds follow a familiar daily pattern of midday highs and nighttime lows. At BOD loadings commonly used, the oxygen highs may reach 30 mg/l or more between noon and 6 PM; still, the total respiratory rate may be sufficient to deplete the oxygen resources during the night. Because of the unfortunate circumstances of rapid photosynthesis during the day, none at night, and a continuous respiratory demand, the available oxygen is not and perhaps cannot be used efficiently. The problem is illustrated in Figure 3.

Another question arises as to how to prevent loss of oxygen to the atmosphere during illuminated periods so that it can be used to prevent serious oxygen depressions at night. One likely possibility is to induce vertical circulation which will provide uniform distribution in spite of differential production of oxygen in relation to depth. In the absence of natural circulation, such differences become pronounced, as shown in Figure 4. Anaerobic conditions prevail at and near the bottom, there is an oxygen surplus near the surface, and the oxygen stores available at sundown commonly are not sufficient to meet respiratory demands during the night. If surplus oxygen could be offered to the oxygen-deficient deeper water, either by bringing the bottom water to the top or the top water to the bottom, algae could be made a more effective source of oxygen.

Disadvantages of Algae as a Source of Oxygen

In comparison with oxygen sources in conventional waste treatment, algae leave much to be desired. Their response to a complex changing environment usually is unpredictable. Critical environmental factors are solar radiation, opacity of the medium, rate of bacterial activity, rise or fall of nutrients, temperature, season, ice cover, ecological succession, and others perhaps even less well understood. Still other disadvantages are often overlooked in the current enthusiasm for using stabilization ponds.

One disadvantage, at least in ponds with long detention, is that algae respond so well to the nutrients in sewage that oxygen required for respiration of the resultant algal mass alone far surpasses the BOD of incoming sewage. This may be compared with a machine that uses 95 per cent of the product just to keep the wheels turning. Pond data that show this appear diagrammatically in Figure 5. Here the biological system grown on sewage had an oxygen use rate of 0.7 g/hr/sq m, whereas only 0.04 g/hr/sq m was needed to stabilize the sewage. This situation undoubtedly could be improved by shortening detention time,

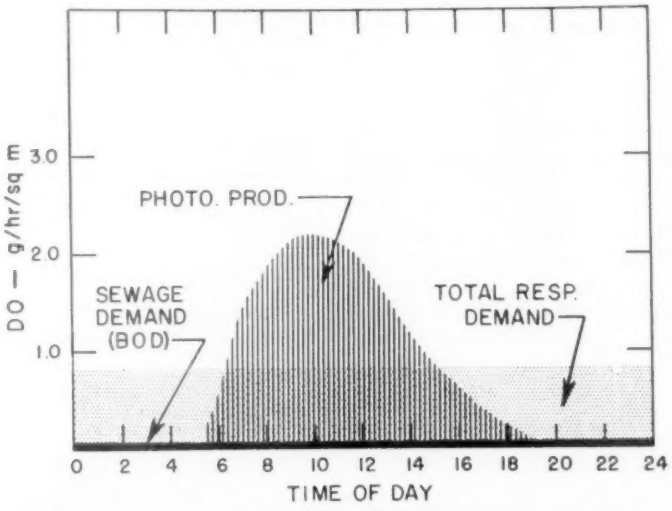

FIGURE 5.—Oxygen relationships in a typical stabilization pond (From Bartsch and Allum—Ref. 16).

cropping the algae, or by any other procedure that would curtail algal respiration.

The goal of waste treatment is effective separation from water of the various substances added to it during use. In these stabilization ponds the original sewage organics are replaced by a similar quantity in the more stable form of living algae. As long as they persist in the final product, the job of treatment is not really complete. Sooner or later, in the pond or in some receiving stream, oxygen must be supplied for decomposition of the algal mass. However, this ordinarily can be tolerated in streams because of the way algae respond to the new environment. As they are swept along downstream, some of them continue to contribute oxygen through photosynthesis; others die off in such pattern that algal respiration is replaced only gradually by the more rapid use of oxygen as the algae decay. As a consequence, it would be expected that the influence of such algae on streams would be reflected principally as greater extremes in the diurnal oxygen pattern.

The fact that algae may persist for some time also gives them potentialities for causing taste, odor, and other treatment problems in water supplies. In some places the green color imparted to the water has been objectionable.

Although BOD reduction is usually accepted as a measure of treatment efficiency, this relationship is almost meaningless when it involves algae-laden effluent samples. With the standard BOD test, and its 5-day incubation in the dark, the sample will give an unduly high value because of algal respiration, death, and decay. Such response can be demonstrated in the laboratory and has been observed repeatedly in natural waters (22) (23) (24). Incubation with continuous illumination results in low or even negative BOD. Exposure to intermittent natural lighting is more instructive but does not measure effluent strength on the same terms as raw sewage strength. These deficiencies of the BOD test have not yet been remedied.

Still other problems arise where algae are to be harvested as a crop. Among them are mechanical and economic complications in separating the crop from the medium; these are under study. In addition, although a uniform crop is desired, both quality and quantity change unpredictably from day to day. More knowledge is needed on basic algal ecology before effective crop control can be practiced.

These, then, are some of the factors to be considered in using algae as a source of oxygen in waste treatment. They contribute little to the function of trickling filters but are necessary in stabilization ponds. The somewhat theoretical questions of advantage and disadvantage raised here relative to their function in such ponds are not intended to discourage their use. To the contrary, such facilities are now serving several hundred American municipalities in a wholly acceptable manner. It seems likely now that algae will serve in this capacity for some time to come, and for this reason there is pressing need to understand their real value and to use them more effectively.

Acknowledgment

The helpful suggestions of W. B. Horning, II, Dr. W. M. Ingram, Dr. J. K. Neel, W. W. Towne, and Dr. E. C. Tsivoglou are gratefully acknowledged.

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TV DOCUMENTARY FILM

You are again reminded of the television documentary program on water pollution, to be shown on ABC, Wednesday, March 29, at 10 PM, EST.

This is part of the Bell and Howell "Close-Up" series and will give a comprehensive coverage of the water pollution problem now and in the next 10 years.

Check your local listings for the ABC station in your area.

USE OF ELECTROPHORETIC SERUM SEPARATION IN FISH STUDIES

Masaru Fujiya

In recent years the paper electrophoretic method of blood serum separation was developed for use in the clinical diagnosis of human ailments. In the fisheries' research field, this method has been applied occasionally to physiological experiment. But in research work on water pollution, the method has not yet been used.

Believing that application of the technique might lead to a way of estimating the effects on fish of low concentrations of wastes, a program of study was executed. Restated, the objective was to find a means of detecting incipient toxication now escaping detection by general bio-assay methods.

Method

Almost all particles under the influence of external voltage will migrate to the electrodes according to their electrical properties. If the materials dissolved or suspended in any ionic solution are made to migrate in this way, the different constituents will travel different distances. Therefore, it is possible to detect individual constituents from some mixtures.

The paper electrophoretic method makes use of this phenomenon; it has been applied to several research fields and called, variously, paper electromigration, paper ionophoresis, and ionography.

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Apparatus

The apparatus is made from two parts, the power source and the chamber. The power source should be able to supply continuously a direct current stabilized for its output power at from 0 to 500 v. Although many kinds of power-source apparatuses are available commercially, the one used here was laboratory-made. It is a simple structure, but satisfactory enough for the separation of fish serum.

The separating operation should be done under fixed conditions, especially with respect to temperature and humidity. The best way of satisfying these conditions is to perform the separation in a closed chamber with a little water.

The chamber shown in Figure 1 was used for this experiment. Three operations could be carried on at the same time. Electrodes such as platinum, silver, and carbon can be tried and the most suitable one for the sample should be chosen. When silver chloride is used as an electrolyte, better results can be expected if a silver electrode is used. On the other hand, different kinds of buffer solutions may be needed with other electrode systems and samples. In the separation of fish serum, the Veronal buffer solution gives good results. This is prepared by adding 10.30 g of Veronal-Na (sodium diethyl barbiturate), 1.84 g of Veronal (diethyl barbiturate), and diluting to 1,000 ml with distilled water (solution pH, 8.6; ionic strength, 0.05).

To detect the pattern of migration,

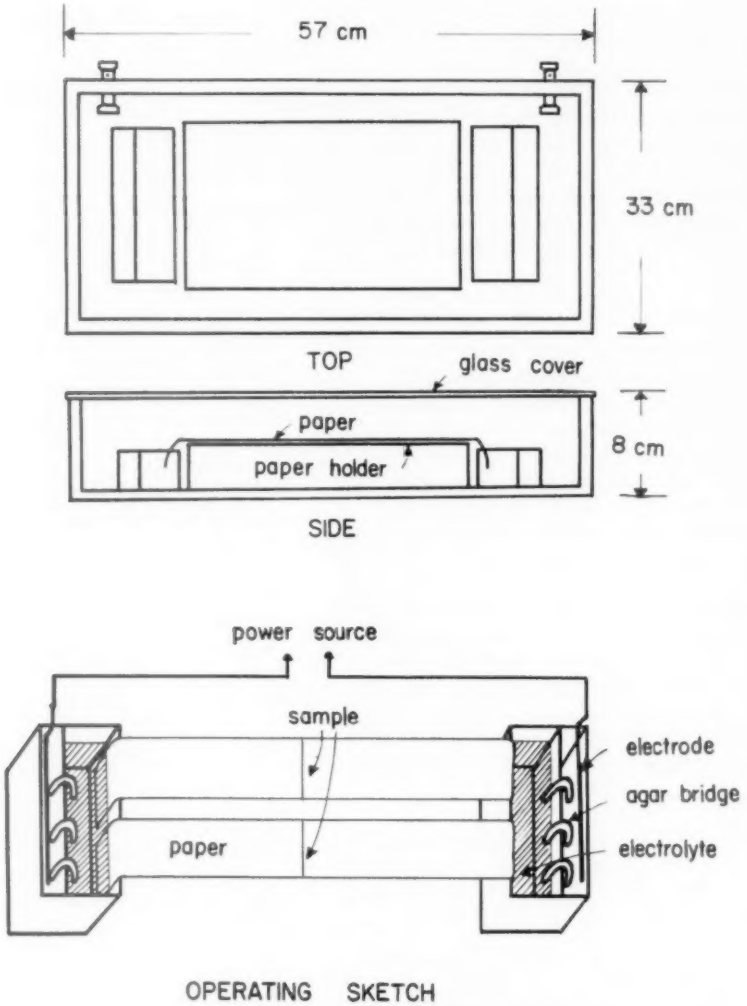

FIGURE 1.—Electrophoresis cell.

a dye is used since the serum of fish is colorless and transparent. A BPB solution was used here, and prepared as follows: add 0.05 g of bromphenol blue, 1.0 g of mercuric chloride, 2 ml of acetic acid, and dilute to 100 ml.

Operation

The paper is arranged in the chamber and 0.02 ml of sample is placed on it, then the voltage is applied. In general, the impressed voltage is closely related to the results of separation. When the operation is made under a strong current, there may be some negative effects, one being the generation of heat which has a harmful effect on protein such as serum. Accordingly, the current should be chosen carefully. For fish serum, a current of 0.5 ma /cm of paper width for 5 hr is satisfactory. Excellent results can be obtained with

a Whatman No. 1 filter paper 4 cm wide using a current of 2.0 ma.

Preparation of Serum Sample

Serum is obtained from the blood collected from the amputated anal part of the fish. The blood after standing in a glass dish divides into two parts, the serum and the clot. The serum is collected and centrifuged to insure the absence of clots.

Comparison of Electrophoretic Pattern

A pattern dyed in BPB solution is detected as spots of yellow color. It is washed with 2 per cent acetic acid to eliminate the excessive dyeing solution on the paper and then exposed to ammonia vapors to change the yellow color to blue. Following this, the paper is coated with paraffin. The migration distance and density of the patterns are illustrated graphically after measuring them with a densitometer. The graph is called the paper electrophoretic curve and its shape indicates physiological conditions. Sometimes the curves can be compared with the naked eye if there are great differences between them.

Fishes Studied

Serum from the following fishes (nine marine and one carp) obtained from fishermen's boats were studied here:

1. *Pagrosomus major* (Temminck and Schlegel),
2. *Sparus swinhomis* (Gunther),
3. *Sebastodes inermis* (Cuvier and Valenciennes),
4. *Acanthogobius flavimanus* (Temminck and Schlegel),
5. *Platycephalus indicus* (Linne),
6. *Astroconger myriaster* (Brevoort),
7. *Spheroides rubripes* (Temminck and Schlegel),
8. *Raja kenojei* (Muller and Henle),
9. *Cynias manazo* (Bleeker), and
10. *Cyprinus carpio* (Linne).

Effect of Raising Fish Without Feeding

Frequently, in bio-assay work, it is necessary to expose fish to toxic substances for long periods. In these experiments, an evaluation of the effects of aquaria breeding and malnutrition was considered necessary if the additional effects of toxic substances were to be discerned. Thus, the objective was to record the range of electrophoretic curves under normal laboratory conditions.

Several fish of *Astroconger myriaster* sp. were used for this experiment. They were raised in an aquarium of running water without feeding for 77 days. A few were removed and sacrificed after the 9th, 33rd, 63rd, and 77th days. During the experiment, the fish were not fed. In general, fish used in the later experiments would have been fed; therefore, results with fish raised without feeding would doubtless be a more conservative baseline from which to assess effects of toxic materials.

Results

Comparison of Electrophoretic Curves for Several Fishes

The electrophoretic curves for several kinds of fishes are shown in Figure 2. The pattern of normal fish serum is divided into four spots on the paper, thus the four peaks for each curve. Generally, normal human serum also has four peaks on the paper electrophoretic curve, named: Albumine, α-globulin, β-globulin, and γ-globulin. In the comparison of human serum with fish serum there is disagreement. Some say it is unreasonable to compare the curves directly, but others hold that both curves might show approximately the same material.

The fish used in this experiment were divided into two races from a point of taxonomy—*Elasmobranchii* and *Teleostomi*. Through the results shown in Figure 2, a capital difference between them was observed. The paper

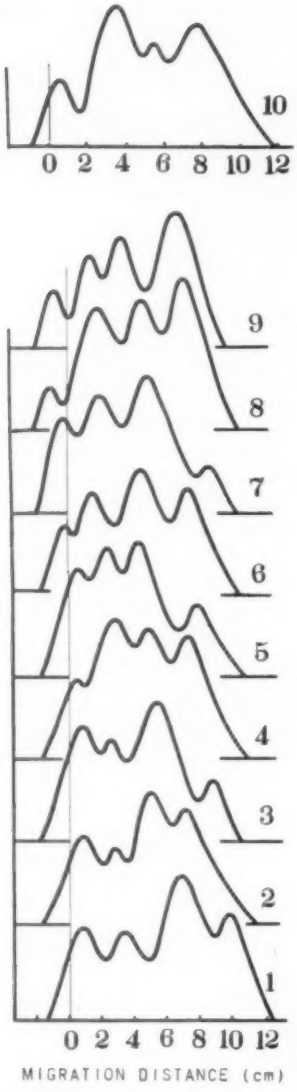

FIGURE 2.—Electrophoretic curves for several fishes: (1) *Pagrosomus major;* (2) *Sebastodes inermis;* (3) *Sparus swinhomis;* (4) *Acanthogobius flavimanus;* (5) *Platycephalus indicus;* (6) *Astroconger myriaster;* (7) *Spheroides rubripes;* (8) *Raja kenojei;* (9) *Cynias manazo;* and (10) *Cyprinus carpio.*

electrophoretic curves of Elasmobranch serum have a peak at the cathode side of the paper, but all peaks of Teleost serum exist at the anode side. Although there are some differences in the shapes of the Teleost curves, they seem to be approximately the same, especially the migration distance of the peak. At any rate, comparing these curves with curves for serums from fish exposed to toxic materials seems to be a valid way of measuring deleterious effects.

Effects of Raising Fish Without Feeding

The result of this experiment on several fish of the species *A. myriaster* is shown in Figure 3. In the figure, there is nothing unusual in the shape of curves until the 63rd day, when the peaks shifted. Inasmuch as the experiments probably would cover a period no longer than eight weeks, and

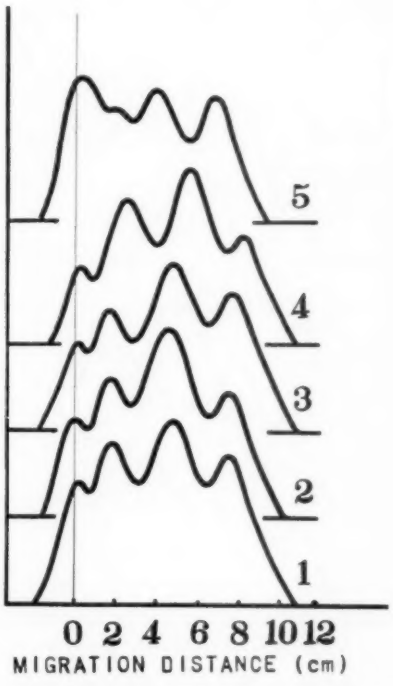

FIGURE 3.—Electrophoretic curve changes of *A. myriaster* raised without feeding: (1) control; (2) after 9 days; (3) after 33 days; (4) after 63 days; (5) after 77 days.

that the fish would be fed, it was concluded that divergences from control curves would indicate changes due to exposure to the toxic material.

Effects of Industrial Wastes and Chemicals

Test fish were exposed in water containing several chemicals and wastes. The results are explained below:

1. Copper sulfite.—Carp, 20 cm long, were exposed to waters containing copper in the concentrations of 0.1, 0.2, 0.5, 1.0, and 2.0 mg/l for 24 hr. The electrophoretic curve for each concentration is shown in Figure 4, and other observations are recorded in Table I. TL_m values of copper to carp have been reported by many persons and show a wide range. So complicated is the relationship between the resistance of fish and toxicity of copper that it is nearly impossible to adapt the results of other studies to this experiment. Therefore, the TL_m value (5 mg/l Cu) for the test run was studied in relation to the specific curves developed for the same test. There was a remarkable difference when the

TABLE I.—Effect of Copper on Carp

Copper (mg/l)	Condition of Fish	Hemoglobin of Blood (g/100 ml)
0.1	Normal in action. A small amount of mucus on surface of body.	9.7
0.2	Same as above.	8.5
0.5	Slow action after 24 hr. Mucus on surface of body.	10.0
1.0	Fish on side after 24 hr. Much mucus on surface of body.	11.0
2.0	Fish on side after 4 hr and dead after 24 hr. Much mucus.	7.0

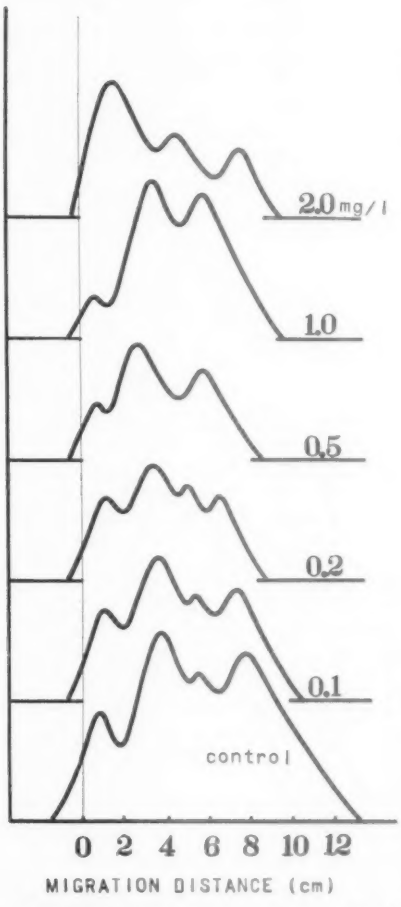

FIGURE 4.—Change in electrophoretic curve for carp exposed to varying concentrations of copper.

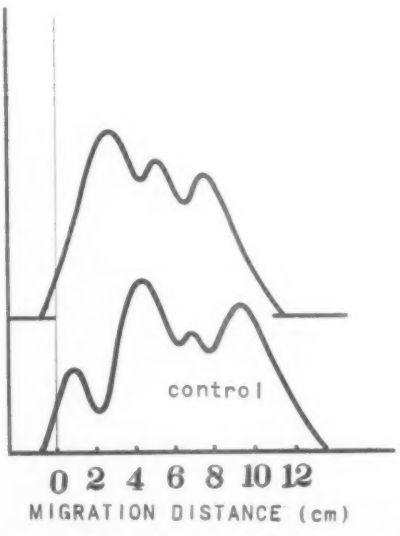

FIGURE 5.—Effect of lead on electrophoretic curve for carp.

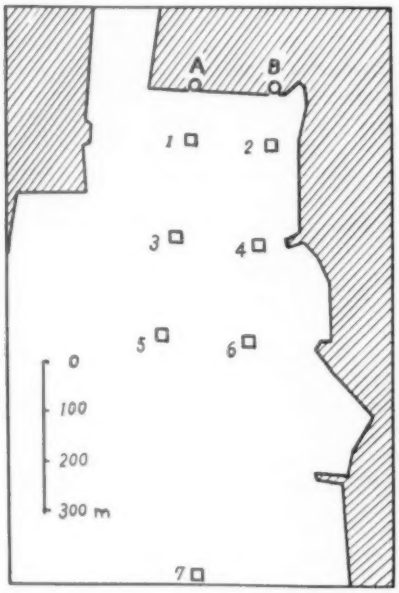

FIGURE 6.—Location of sampling stations.

copper content was 0.5 mg/l, and it is concluded that the threshold concentration inducing harmful effects is between 0.2 and 0.5 mg/l Cu.

2. Lead acetate.—The lead experiment was not done in the same way as the copper test. Ten test fish, carp, were raised for 40 days in water containing 1.0 mg/l Pb. Dead specimens were recovered on the 9th, 20th, and 21st days. Seven fish survived the whole period, but almost all were oversensitive and a slight stress shocked them. The electrophoretic curves in Figure 5 demonstrate the large differences between lead-exposed and normal carp serum. Again, as with cop-

TABLE II.—Environmental Conditions and Surviving Specimens at Sampling Stations *

Station	Remarks	Survivors
1	Water of low concentration (10-50 mg/l COD) always present.	2 of 3
2	Same as above.	1 of 3
3	Water of low concentration sometimes present.	2 of 3
4	Same as above.	3 of 3
5	Water of low concentration seldom present.	2 of 3
6	Same as above.	3 of 3
7	No influence.	3 of 3

* Only surviving fish were examined.

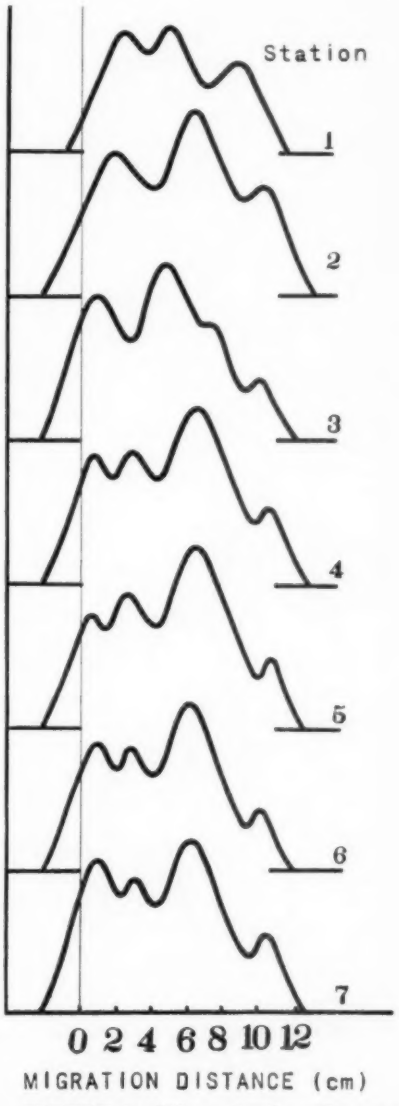

FIGURE 7.—Effect of pulp mill wastes on *S. swinhomis* at the various sampling stations.

per, the TL_m values of lead variously reported are impossible to adapt to the immediate experiments. In these tests, the carp survived for 24 hr in a concentration of 50 mg/l Pb. However, the long-term exposure to a much lower lead concentration, 1.0 mg/l, resulted in a harmful effect to their serum.

3. Sodium hydroxide and sulfuric acid.—As a preliminary test, carp were exposed to several concentrations of these chemicals for 24 hr. For sodium hydroxide, there was a significant change in the paper electrophoretic curve when the concentration reached 40 mg/l, and the most remarkable changes were observed at 60 and 90 mg/l. On the other hand, the concentration of 20 mg/l of sulfuric acid made a very marked change to the fish serum. In this case, a histological change on the gills was observed with the naked eye, a symptom connected with the phenomenon shown in this experiment, the change of the paper electrophoretic curve of the serum.

4. Pulp mill waste.—This experiment was tried to study the effect of the waste to fish *in vivo* in the fall of 1958. The topography of the field and the sampling stations are shown in Figure 6. In the figure, there is a Kraft pulp mill in the most inner part of the bay, having two outfalls for the wastewater, *A* and *B*. Outfall A is the main one, discharging about 46,000 tons/day which is distributed over an area of about 800 m radius. Usually, the COD concentration of the wastewater was about 300 to 800 mg/l. The sample fish, *Sparus macrocephalus*, about 25 cm long, were exposed for 24 hr in crawls at the stations shown in the figure. Three sample fish were

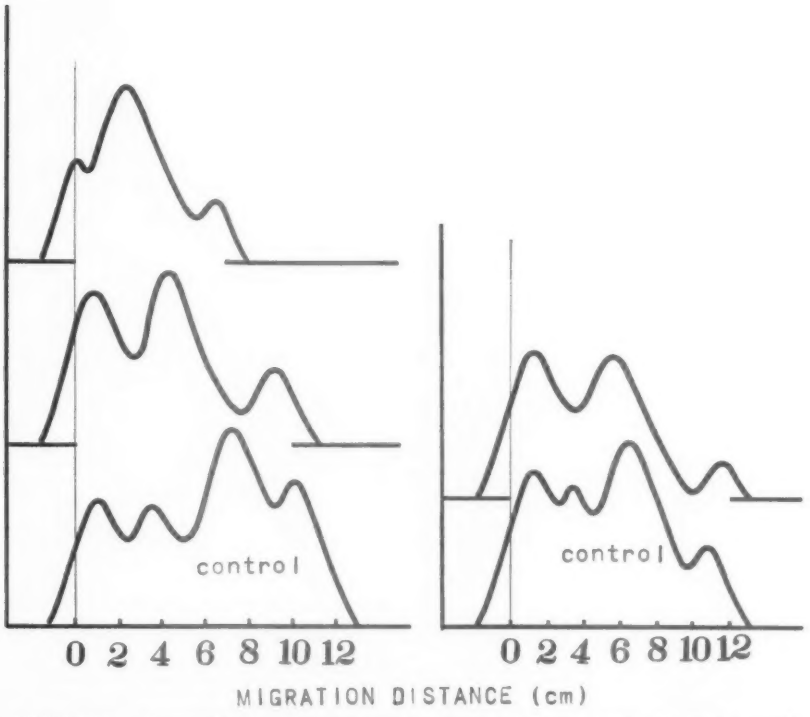

FIGURE 8.—Comparison of electrophoretic curves for fish on their side and normal specimens. Curves on left are for *P. major:* on right, for *S. swinhomis.*

exposed at each station. Their survival after 24 hr is shown in Table II. Serum samples were collected only from surviving fish. The electrophoretic curves obtained are shown in Figure 7. Fish exposed to the wastes at Stations 1, 2, and 3 show great differences in comparison with others. From the fact that each fish treated seemed to be full of life, it is believed that the paper electrophoretic method is valuable for estimating incipient harmful effects of the waste on fish.

5. Serum changes in fish found on their side.—There are many difficulties in raising marine fishes in aquaria. During these investigations, several fishes died from unknown causes, and the serum changes were measured. Two fishes, *Pagrosomus major* and *Sparus swinhomis*, which fell on their side were tested. Results are shown in Figure 8 and the differences between the normal and sick fish are plain.

Discussion

Electrophoretic Method

The method used in this investigation was nearly the same as that used in medical science. Although the electrical conditions connected with the technique might influence the results, the only obvious influencing factor was the way the serum was preserved. Serum preserved in an ice chamber over seven days did not show a normal pattern, but the preservation for five days or less caused no trouble.

Difference in Fish

From the biological viewpoint, individual specimen variation is the most important problem in the interpretation of results. Experience here is that cultured fish such as carp had many individual serum variations. On the other hand, wild fishes showed stable patterns. This stability may be a manifestation of the "survival-of-the-fittest" effect of a natural habitat. With cultured fish, the weak as well as the strong may survive. Perhaps through breeding, this problem can be eliminated, but until then, allowances must be made for variations.

Applicability of Method

Results of this study clearly indicate that the paper electrophoretic method of serum analysis is an excellent way of finding an effect of industrial wastes on fish. Normal fishes always have four peaks on the electrophoretic curve and the shape is stable for each fish. On the other hand, fish affected by wastes exhibit a characteristic change in their serum which might be related to other symptoms. In the tests of pulp mill wastes, there was a remarkable relationship between the quality of the water at each station and the condition of the test specimens.

Summary

1. The paper electrophoretic method of examining fish serum and its applicability to biological studies of the water pollution problem are discussed and recommended.

2. It is found that there are some differences between the serums of *Elasmobranchii* and *Teleostomi*, but that they have approximately the same composition, and exhibit characteristic electrophoretic curves from which deviations can be measured.

3. Serums of fish exposed to certain concentrations of materials such as pulp mill waste and inorganic chemicals are noticeably different from serums of unexposed fish. This is true even when the concentrations were below those necessary to cause any outward sign of distress.

BOD REMOVAL AND SLUDGE GROWTH IN THE ACTIVATED SLUDGE PROCESS

Brother Joseph McCabe and W. Wesley Eckenfelder, Jr.

Intensive study of the biological oxidation process during the past few years has provided many of the basic relationships needed to obtain economical design, efficient operation, and effective modification. This paper presents some of the formulations available to the engineer for predicting BOD removal and sludge growth under various phases of the biological treatment process.

Formulas

The removal of organic material from wastewaters by the activated sludge process can be attributed to "biosorption" and assimilation. Bacteria utilize the organic substrate for energy, with the production of carbon dioxide and water, and for synthesis of new cellular protoplasm, resulting in sludge growth. Removal due to "biosorption" by the sludge solids present during an initial period of contact results in the storage of nutrients for later assimilation. A mathematical formulation of the removal of organic matter (BOD) during activated sludge growth has been suggested by the authors (1) (2) based on the kinetics of microbiological growth as it occurs in bio-oxidation systems.

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This paper was presented at an American Chemical Society Symposium held in Cleveland, Ohio, April 1960.

At the beginning of the oxidation period let:

S_0 = the initial sludge mass, and
L_0 = the total amount of organic material (BOD) initially present that can be oxidized as a limit of the oxidation process.

At any time t let:

S = the sludge concentration present,
$\Delta S = S - S_0$ = the increase in sludge concentration,
y = the BOD removed, and
$L = L_0 - y$ = the oxidizable BOD remaining.

Let a be the fraction of the BOD removed which is synthesized to sludge and $(1 - a)$ the fraction which is used for energy. Then $ay = \Delta S$ and, at any time,

$$S = S_0 + \Delta S = S_0 + ay \quad \ldots\ldots (1)$$

Figure 1 is a typical growth curve for an activated sludge mass plotted against time in a batch oxidation started at a high L_0/S_0 ratio. This growth curve exhibits three distinct phases:

Phase I.—A constant growth phase $(a\text{–}b)$;
Phase II.—A declining growth phase $(b\text{–}c)$; and
Phase III.—An auto-oxidation phase $(c\text{–}d)$.

The first two phases follow the typical sigmoidal growth curve exhibited by all biological populations limited in

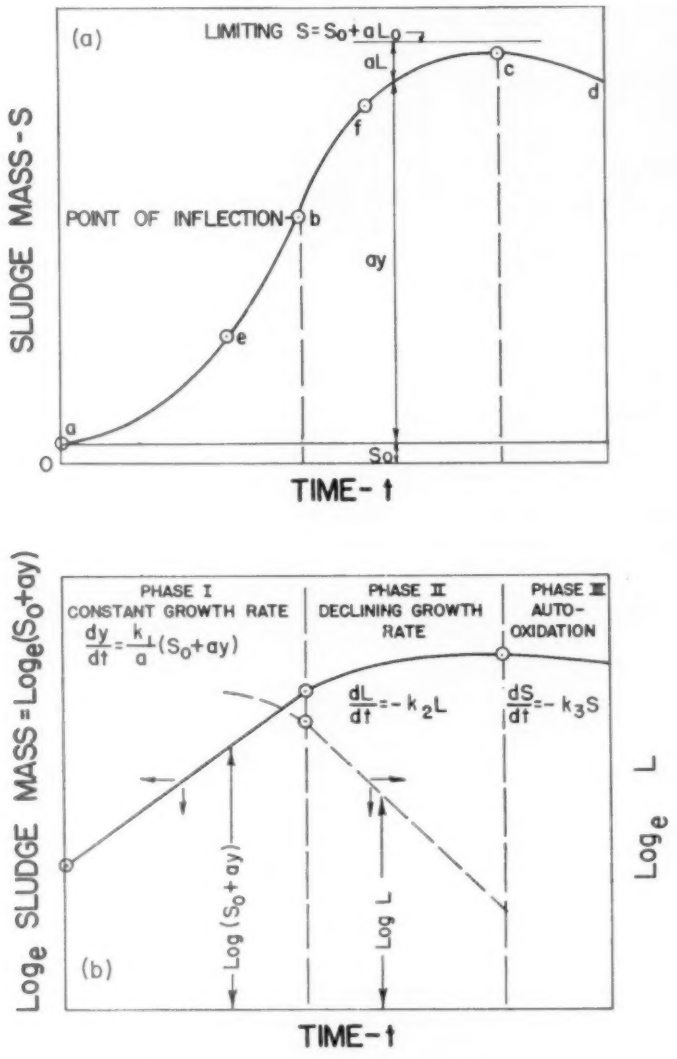

FIGURE 1.—Ideal activated sludge growth curve.

space or food. The mathematical formulation of this S-curve as a continuous function has been presented by Fair and Moore (3) together with its approximation as a two-phase discontinuous function. The solution of the two discontinuous functions is simple and direct, and this formulation appears to provide sufficiently accurate results for engineering studies. Garrett (4) and Garrett and Sawyer (5) found that the growth of activated sludge follows this discontinuous function, constant at high BOD values and directly proportional to the BOD present at low concentrations.

Phase I—Constant Growth Phase

The two-phase formulation assumes that the growth rate in Phase I (a to b), in the presence of an abundant supply of food, is limited only by the minimum generation time of the organisms themselves for the temperature used. Thus regular and maximum multiplication occurs, and the growth rate is a constant maximum. Phase I can, therefore, be defined by a constant rate of sludge increase:

$$\frac{dS}{dt} = \frac{d(S_0 + ay)}{dt} = k_1 S \ldots . (2)$$

which integrates to

$$\frac{\log_e (S_0 + \Delta S)}{S_0} = k_1 t \ldots . (3)$$

or, in terms of BOD removal y, and assuming for the present no initial removal,

$$\frac{\log_e (S_0 + ay)}{S_0} = k_1 t \ldots . (4)$$

where k_1 is the logarithmic growth rate for natural logarithms; the constant for common logs is K_1.

The plot of $\log_e S_0 + ay$ against t (shown as solid line in Figure 1b) is a straight-line function within Phase I (a–b) where the slope defines k_1. The decreasing slope of the line after point b indicates the declining growth rate of Phase II.

Phase II—Declining Growth Phase

At some transition point, b, the food concentration is just sufficient to maintain the maximum multiplication of the bacterial population present. Beyond this point of discontinuity, the growth rate is controlled by and is proportional to the limited concentration of food. For single organic compounds, the rate of BOD removal is directly proportional to the BOD remaining and Phase II can be defined by a constant rate of BOD decrease:

$$\frac{-dL}{dt} = k_2 L \ldots . (5)$$

which integrates to

$$\log_e \frac{L}{L_0} = -k_2 t \ldots . (6)$$

where k_2 is the logarithmic BOD removal rate for natural logarithms. The constant for common logs is K_2. The plot of log L against t (shown by the dashed line in Figure 1b) is a linear function within Phase II where the slope defines k_2. It is often convenient to plot log L/L_0 against t to compare oxidations under various conditions.

Using quantitative determination of the substrates themselves, Wuhrmann *et al.* (6) and others have shown that the rate of removal of pure compounds by bacteria is constant down to very low concentrations (less than 1 mg/l). The kinetics of this zero order removal are explained by the laws governing enzymatic reactions. First order reactions are approximated when nonspecific parameters such as BOD and COD are employed to measure concentrations in simple substrates. BOD removal from the heterogeneous mixtures encountered in sewage or industrial wastes usually yield a progression of decreasing rate constants as the less readily assimilable BOD is removed; first order kinetics do not, therefore, apply directly. The evaluation of progressive k_2 values for such complex wastes is discussed below.

At the transition point b the removal rate due to the constant rate of sludge increase and to the constant rate of BOD decrease are just equal. This point of discontinuity between Phase I and Phase II can be estimated approximately from the inflection point in Figure 1a and from the linearity in Figure 1b. More exact calculations can be obtained by equating Equation 2 to Equation 5 after multiplying the latter by a:

$$\frac{L_b}{S_b} = \frac{L_b}{S_0 + ay_b} = \frac{k_1}{ak_2} \ldots . (7)$$

or

$$k_1(S_0 + ay_b) = ak_2(L_0 - y_b) \ldots (7a)$$

and

$$\frac{y_b}{L_0} = \frac{k_2 - k_1 \dfrac{S_0}{aL_0}}{k_1 + k_2} \quad \ldots\ldots (8)$$

$$\frac{L_b}{L_0} = \frac{k_1 + k_1 \dfrac{S_0}{aL_0}}{k_1 + k_2} \quad \ldots\ldots (9)$$

Then, from Equation 4,

$$t_b = \frac{1}{k_1} \log_e \frac{S_0 + ay_b}{S_0} \quad \ldots\ldots (10)$$

Equation 7 shows that k_2 varies inversely with the L_b/S_b value for any given oxidation system since k_1 and a are taken as constants of the system.

Phase III—Auto-Oxidation Phase

In Figure 1, Phase III shows the decrease in sludge mass by self-metabolism or auto-oxidation of cellular protoplasm as the available food becomes depleted. Some residual BOD remains even after long aeration periods, and this residual usually increases with the length of time in Phase III. This is attributed to the release of cellular constituents after the cell dies. This auto-oxidation phase is utilized for the aerobic digestion of sludge solids.

During Phase III, biological sludge assimilated during the growth phases undergoes continuous auto-oxidation (Figure 1, *c* to *d*). The oxidation rate will initially approximate first-order kinetics. As oxidation proceeds, the cellular constituents remaining are more difficult to oxidize and the oxidation rate will decrease. The process can then be formulated by a composite exponential or by a retardent-type reaction (such as Equations 14, 15, and 17 given below). Results from activated sludge synthesized from a pharmaceutical waste are shown in Figure 2. Since a portion of the cellular material is resistant to oxidation, there will be a non-oxidizable residue remaining.

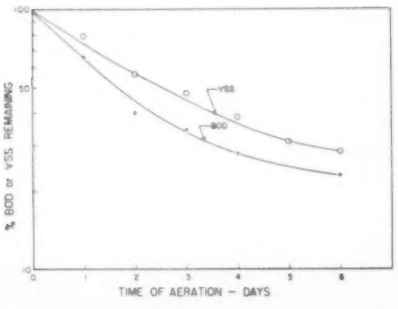

FIGURE 2.—Decrease in BOD and volatile suspended solids by auto-oxidation.

Sludge Growth Ratio, a

The growth ratio a used above was defined as the fraction of BOD removed which is synthesized to new sludge; it was assumed to be constant. This is only approximately so since the ratio varies with age of the sludge, quantity of available nitrogen, etc. Determination of the synthesized fraction is further complicated by biosorption and auto-oxidation. Engelbrecht (7) showed that for many pure substrates the ratio of biological solids to BOD removal increased sharply to a point of discontinuity and dropped off to a constant (approximately $\frac{2}{3}$ of ultimate BOD) thereafter. This was attributed to adsorption and subsequent assimilation of stored material.

It is probable that a portion of cellular protoplasm is continually being oxidized. Gaudy and Engelbrecht (8) point out that the rate of endogeneous respiration is not constant and that its course or existance cannot be determined exactly when substrate is being oxidized. However, average values for the amount of self-metabolism are sufficiently accurate to estimate sludge growth for engineering studies. If b is the sludge fraction consumed during continual endogeneous respiration then

$$ay = S + bS_a \quad \ldots\ldots (11)$$

where S_a is the average sludge concentration. From data on BOD removal and its associated sludge growth, the a value can be approximated as the slope of a plot of $\Delta S/S_a$ vs. y/S_a as

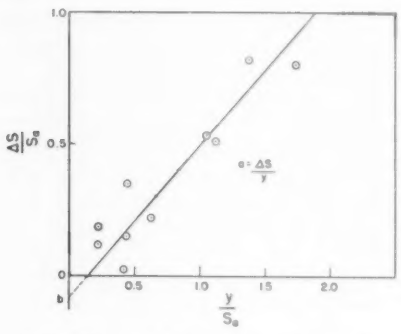

FIGURE 3.—Calculation of a from BOD removal and solids buildup data.

shown in Figure 3. The intercept of the slope of zero BOD removal is interpreted as an approximation of b. This approach must be used with caution to interpret the amount of stored material initially removed by biosorption.

Determination of a from oxygen utilization data is preferable because of the interference of inert solids in the measurement of sludge growth. The ratio of oxygen utilization and BOD removal a' is estimated as the slope of a plot of O_2/S_a vs. y/S_a. The growth ratio can then be derived, on the basis of ultimate BOD, by converting from oxygen units to volatile solids units where $O_2/\Delta S^* = 1.4$. Then

$$a = (1 - a')/1.4 \quad \ldots\ldots (12)$$

Active Sludge Fraction

The foregoing discussion has been based on the definition of S as the mass of active biological cellular matter and it is necessary to estimate the initial mass of active bacteria to predict BOD removals accurately. On the other hand, an estimation of gross sludge solids is required to predict the amount of excess sludge for ultimate disposal.

The usual determination of volatile solids content will not give a valid estimate of active cellular content especially when the sludge contains inert organic as well as inorganic matter. The oxygen uptake rate will provide information on the active sludge fraction when the a' and b constants discussed above are determined. McKinney (10) reports that organic nitrogen in the biological solids can be used to indicate active solids unless inert nitrogen-containing compounds accumulate.

An accurate, if laborious, method was employed by Stern (11) who inoculated a given weight of activated sludge into nutrient broth and estimated the increase in weight during aeration after centrifuging. Extrapolating the log-growth curve back to zero time gave the true initial biological sludge mass which in turn, when divided by the initial gross weight, gave the active sludge fraction. Employing this procedure, Stern obtained an active fraction of only 24 per cent for an activated sludge with a very large pulp and fiber buildup.

Examples of the Two-Phase Formulation

Simple Substrate

The two-phase formulation of BOD removal during bio-oxidation is defined by the constants a, S_0, L_0, k_1, and k_2. An example for a simple substrate without initial removal is shown in Figures 4a and 4b. Experimental data were obtained from Garrett's curves for BOD reduction and oxygen utilization in a peptone substrate by activated sludge at 25°C (4). The feed BOD was reduced by a third after mixing with the sludge. Since no further adsorption was apparent thereafter, assimilation was assumed to be responsible for all further BOD removal. Curves B and C with identical L_0/S_0 ratios, four times that of Curve A, followed parallel K_1 and K_2 rates and exhibited a more extended Phase I than Curve A. The K_1 rate was constant for the system and consequently, according to Equa-

* In practice this $O_2/\Delta S$ ratio varies between 1.2 and 1.5. Porges *et al.* (9) computed the value of 1.4 for a sludge composition of $C_5H_7NO_2$.

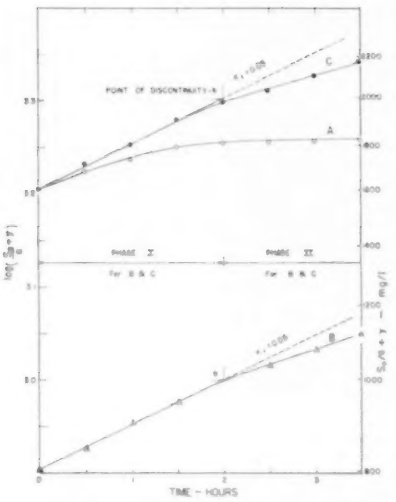

FIGURE 4a.—BOD removal by activated sludge—peptone substrate (data after Garrett (4)).

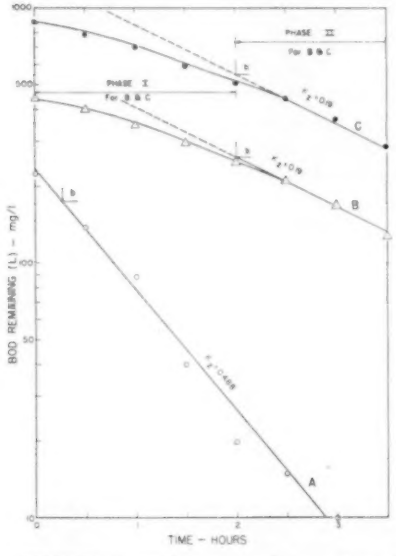

FIGURE 4b.—BOD removal by activated sludge—peptone substrate (data after Garrett (4)).

tion 7, K_2 should be inversely proportional to the L_b/S_b ratio at the transition point. The point of discontinuity is defined not by a limiting BOD but by the L_b/S_b ratio; L_b values of 171, 263, and 526 mg/l were calculated. Pertinent data are given in Table I.

TABLE I.—Two-Phase Analysis of Biological Oxidation—Peptone Substrate (Figure 4)*

Item	Curve		
	A	B	C
Feed BOD, mg/l	340	640	136
Initial BOD = L_0, mg/l	225	450	900
Initial TSS, mg/l	1,340	670	1,340
VS, as % of TS	72.4	72.4	72.4
Initial VSS = S_0, mg/l	970	485	970
a (mg/l VSS/mg/l BOD)	0.6	0.6	0.6
L_0/S_0 (mg/l BOD/mg/l VSS)	0.23	0.93	0.93
Initial removal = y_i, mg/l	0	0	0
K_1 (common logs), hr^{-1}	0.05	0.05	0.05
K_2 (common logs), hr^{-1}	0.488	0.19	0.19
k_1 (natural logs), hr^{-1}	0.115	0.115	0.115
k_2 (natural logs), hr^{-1}	1.12	0.435	0.435
t_b, hr	0.3	2.0	2.0
At Point b:			
y_b, mg/l	55	187	374
L_b, mg/l	171	263	526
$S_0/a + y = S_b$, mg/l	1,653	987	1,974

* Experimental data after Garrett (4).

Arithmetic Growth Phase

As noted by Garrett and Sawyer (5), within any portion of Phase I where the

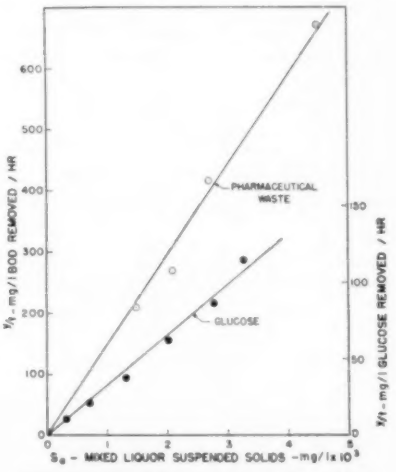

FIGURE 5.—BOD removal relationships during linear growth phase.

per cent increase in sludge mass is not greater than 100 per cent ($\Delta S < S_0$), relatively little error is introduced by letting $S = S_a$, the average sludge concentration over the range under consideration. Then if $t_0 = 0$, Equation 2 becomes

$$y = k_1 S_a t / a \quad \ldots\ldots\ldots (13)$$

which can also be used as an approximate expression for the linear portion (*e–f*) of the growth curve if $\Delta S < S_0$. Figure 5 shows this linear relationship observed in a glucose substrate and a pharmaceutical waste.

Initial BOD Removal

In many biological oxidation systems, a very high initial rate of BOD removal is found immediately after contact of waste with sludge, followed by a slower rate of removal. The magnitude of this high initial rate depends on the nature of the waste and the characteristics of the sludge. Storage of BOD by the microbial cell results when this initial rate of removal exceeds the maximum rate of sludge growth (9). This stored BOD is subsequently oxidized after several hours aeration of the sludge. Ecken-

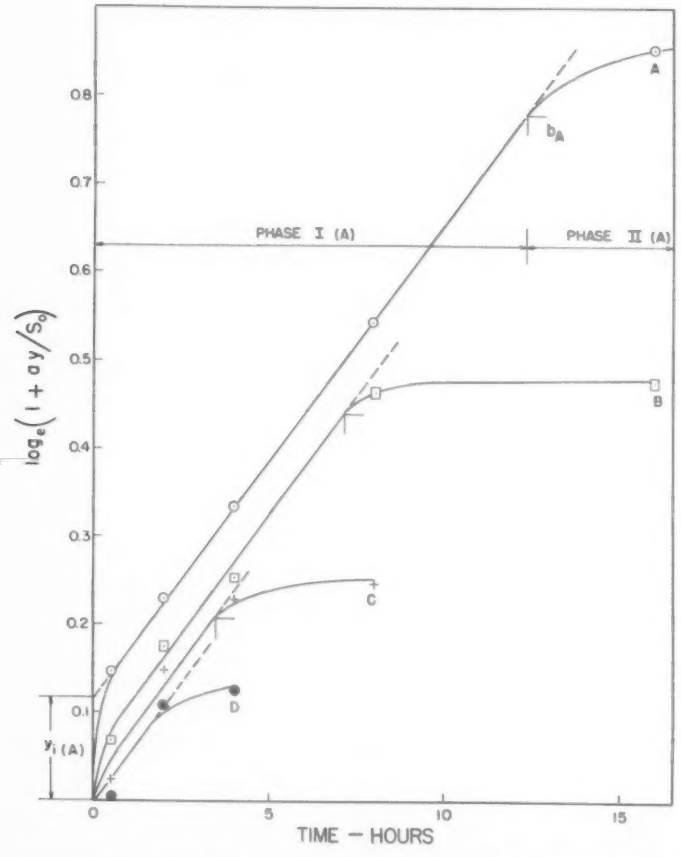

FIGURE 6.—Correlation of pharmaceutical waste data during Phase I BOD removal. Phases I and II and initial removal are denoted only for Run A.

felder (12) found that this high initial rate of BOD removal was a direct function of the sludge solids present when considering only that portion of the BOD which was rapidly removed.

The course of initial removal and Phase I assimilation for a pharmaceutical waste using four different initial activated sludge concentrations is shown in Figure 6. There were sufficient points on Curves *A* and *B* to estimate k_1, and with identical food and sludge sources it is reasonable to expect the same k_1 value for Curves *C* and *D*. Insufficient Phase II data were obtained to determine k_2 values, and the point of discontinuity *b* was estimated by eye. The difference between S_0 and the intercept of k_1 extended to the ordinate was taken to indicate the amount of initial removal.

Engelbrecht (7) showed that the adsorbed material contributed to the mass of biological solids and believed that its utilization by the microorganisms permitted adsorption to continue until the substrate concentration became limiting; then the final amount of adsorbed material was metabolized causing a rapid decrease in the mass of the solids. His data show that the ratio of biological solids to BOD removed increases sharply until the region of the point of discontinuity *b* and drops off thereafter. It may be concluded that adsorbed material removed from solution is not synthesized during Phase I, but that it is utilized during Phase II together with the additional BOD removed during this phase. Consequently, corrected BOD values should be used for the two-phase formulation of removals caused by assimilation.

Complex Wastes

Since most wastewaters contain a variety of organic substances, the semilog plots of BOD remaining show decreasing purification rates in Phase II. This decrease has been expressed mathematically by Fair *et al.* (13) as a retardant formula,

$$\frac{-dL}{dt} = \frac{k_2}{(1+mt)} L \quad \ldots\ldots (14)$$

and by Fair and Geyer (14) as a function of the decreasing availability of substrate,

$$\frac{-dL}{dt} = k_2 \left(\frac{L}{L_0}\right)^n L \quad \ldots\ldots (15)$$

where m is a coefficient of retardation and n is a non-uniformity coefficient. When m and $n = 0$, Equations 14 and 15 are the same as Equation 5.

Figure 7 gives one example of the batch oxidation (20°C ± 1°) of a pharmaceutical waste whose decreasing removal rate in Phase II was calculated by the retardant formula in Equation 14. The S_0 value was in terms of gross suspended solids and experimental values were field BOD data. Calculated data are given in Table II.

It is also possible to approximate the decreasing k_2 removal rate by assuming that the BOD in Phase II is a composition of several simple components:

$$L_0 = L_a + L_b + \cdots + L_n$$

and that each component is oxidized independently and simultaneously according to Equation 5 at its own rate:

$$(k_2)_a, (k_2)_b, \cdots, (k_2)_n$$

Then the total BOD remaining at any time will be the sum of the amounts of each component remaining as de-

TABLE II.—Two-Phase Analysis of Biological Oxidation—Pharmaceutical Waste (Figure 7)

Item	Value
a	0.55
S_0	2,250 mg/l
L_0	5,100 mg/l
k_1	0.069 hr^{-1}
k_2	0.333 hr^{-1}
m	0.05
L_b	1,580 mg/l
S_b	4,180 mg/l

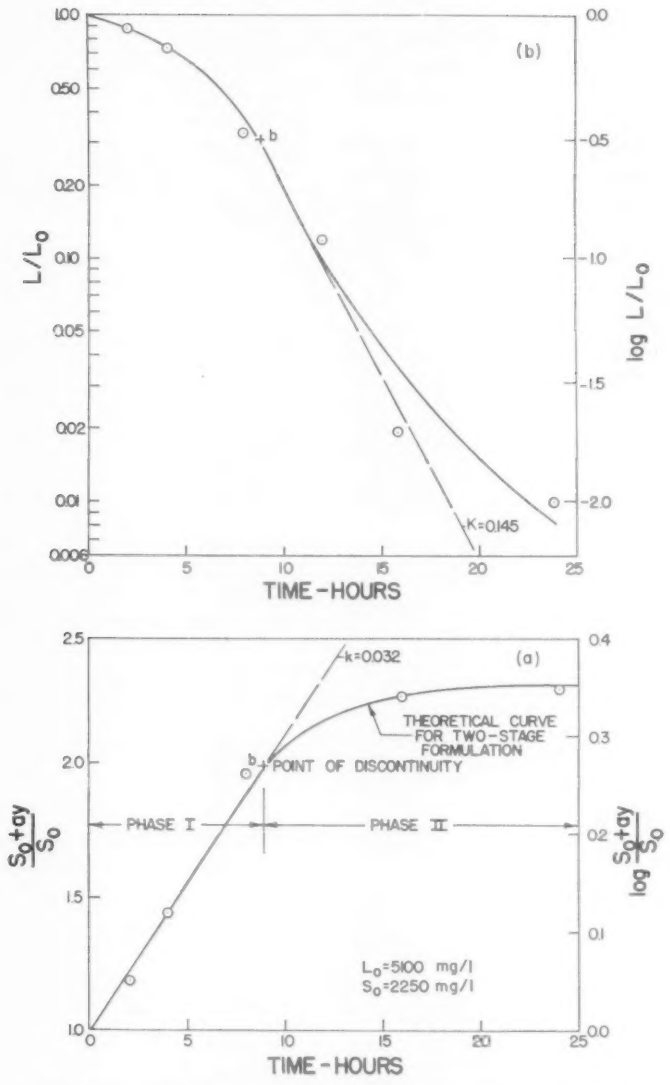

FIGURE 7.—BOD removal by activated sludge—pharmaceutical waste.

termined by Equation 6:

$$L = (L_a)_t + (L_b)_t + \cdots + (L_n)_t \quad (16)$$

The sum of the ordinates of these log functions may be expressed in exponential form:

$$L = L_a e^{-(k_2)_b t} + L_b e^{-(k_2)_b t} + \cdots + L_n e^{-(k_2)_n t} \quad (17)$$

This is the composite exponential used by Theriault and McNamee (15) for the oxidation rate of channel sludges, by Streeter (16) for the death rate of bacteria, by Moore (17) for oxygen utilization rate by activated sludge, and by Gameson and Wheatland (18) for the rate of oxidation of sewage effluents.

TABLE III.—Two-Phase Analysis of Biological Oxidations —k_2 as a function of S_b/L_b

Item	Values						
	Peptone Substrate* (Figure 4)			Glucose Substrate*		Pharmaceutical Waste (Figure 7)	
L_o, mg/l	225	450	900	370	740	5,100	1,075
S_b, mg/l	970	485	970	420	840	2,250†	2,035†
a	0.6	0.6	0.6	0.7	0.7	0.55	0.55
k_1, hr^{-1}	0.115	0.115	0.115	0.122	0.122	0.069	0.069
k_2, hr^{-1}	1.12	0.435	0.435	1.9	1.9	0.333	0.253
m	0	0	0	0	0	0.05	0.05
L_b, mg/l	171	263	526	53	109	1,580	980
S_b, mg/l	1,693	987	1,974	9.7	1,831	4,180	2,087
S_b/L_b	9.7	3.75	3.75	17.3	1.68	2.64	2.13
$k_2/(S_b/L_b)$, hr^{-1}	0.114	0.116	0.116	0.110	0.113	0.126	0.119

* Experimental data after Garrett (4.)
† Gross TSS.

k_2 as a Function of S_a

For any waste oxidation system begun in Phase I, k_1 is a constant and k_2 is proportional to S_b/L_b according to Equation 7 and as indicated generally in Table III for peptone, glucose, and a pharmaceutical waste. However, when batch oxidations of dilute wastes are initiated within Phase II beyond the point of discontinuity, so that the S_b/L_b ratio is never present, experimental data indicate a general direct relationship between the reaction rate k_2 and the average sludge concentrations S_a.

Then Equations 5 and 6 become

$$\frac{-dL}{dt} = k_2' S_a L \quad \ldots\ldots (18)$$

$$\log_e L/L_0 = -k_2' S_a t \quad \ldots (19)$$

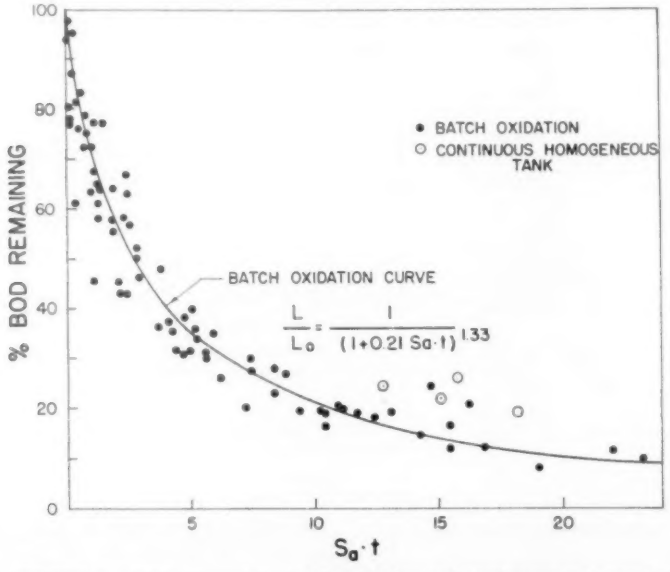

FIGURE 8.—BOD removal for batch oxidation and continuous treatment of a pulp and paper mill waste.

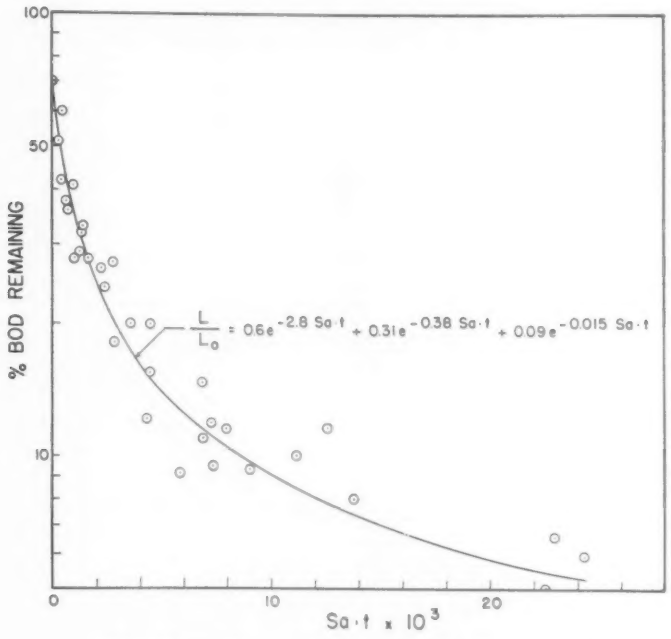

FIGURE 9.—BOD removal by activated sludge—sewage (data after Ruchhoft *et al.* (19)).

These equations are empirical and should be used with caution since their application is limited. Nevertheless, they do allow a degree of prediction,

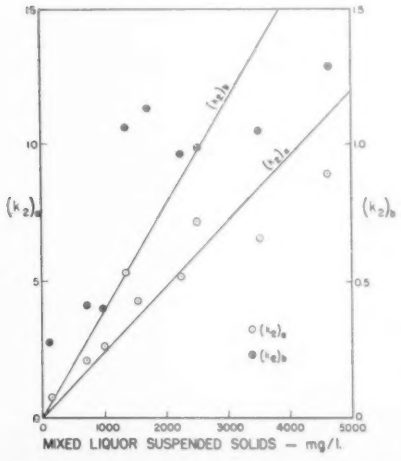

FIGURE 10.—Correlation of BOD removal coefficients with suspended solids during Phase II according to Equation 20.

within limits, for oxidations entirely within Phase II. Thus Figure 8 shows the correlation obtained for Phase II data employing the integrated form of Equation 15 for a pulp and paper mill waste (L_0 = 180 to 250 mg/l BOD).

The solution of Equation 16 using the empirical Equation 18 gives

$$L = (L_{a0}e^{(-k_2' Sa t)_a} + L_{b0}e^{(-k_2' Sa t)_b} + \ldots + L_{n0}e^{(-k_2' Sa t)_n} \ldots \quad (20)$$

The data of Ruchhoft *et al.* (19) on the removal of BOD from domestic sewage during Phase II were correlated according to Equation 20 as shown in Figure 9. The correlation between k_2 and S_a according to Equation 18 is shown in Figure 10. As would be expected for approximately equal concentrations of the same sewage, the BOD fractions L_a, L_b, and L_c were approximately the same for all runs. For systems started in Phase II the first term in Equation 20 probably reflects

TABLE IV.—Rate Constants and Associated BOD Fractions

Waste	$(k_2)_a$ (hr^{-1})	L_a (mg/l)	$(k_2)_b$ (hr^{-1})	L_b (mg/l)	$(k_2)_c$ (hr^{-1})	L_c (mg/l)
Domestic sewage & textile mill	4.35	0.28	0.95	0.55	0.061	0.175
Pulp & paper	1.73	0.17	0.50	0.29	0.051	0.33
Pulping & bleaching	0.95	0.40	0.125	0.60	—	—
Settled sewage	2.8	0.60	0.38	0.31	0.015	0.09

initial removals. Then L_a and k_{2a} would represent the BOD fraction removed by biosorption and its removal rate.

The rate constants and associated BOD fractions for several wastes computed according to Equation 20 are given in Table IV.

Application to Process Design

Design and operation of the various modifications of the activated sludge process can be based on the basic formulations developed above, with attention to the portion of the fundamental sludge growth curve utilized by the process (Figure 11). The portion of the growth curve utilized depends on the L_0/S_0 ratio and the detention period employed. The mathematical formulations employed for each process will be those presented above for the phase in question. It is emphasized that an understanding of the underlying principles of sludge growth allows the design or operating engineer to employ that process modi-

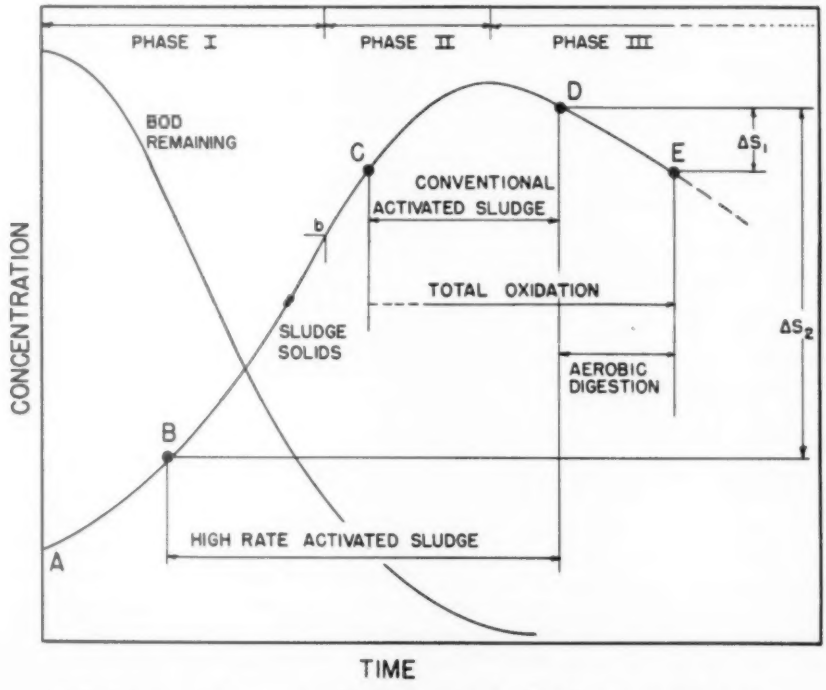

FIGURE 11.—Sludge growth and BOD removal relationships for activated sludge.

fication which is applicable to the particular waste which must be removed.

Conventional Activated Sludge

The conventional activated sludge process begins at low L_0/S_0 ratios, less than L_b/S_b, due to rather dilute wastes and/or high sludge return; this system, therefore, commences within Phase II. The aeration period generally extends into Phase III, and this conventional process occurs between C and D in Figure 11 where the sludge accumulation is denoted as ΔS_1.

High-Rate Activated Sludge

The high L_0/S_0 ratio for the high-rate activated sludge process is obtained by feeding high-concentration wastes or by lowering the returned sludge rate; this system starts within Phase I to exploit the high removal rate due to unrestricted growth. The aeration period (B–D) can extend into Phase III; the sludge accumulation is then shown as ΔS_2.

Total Oxidation

If aerobic digestion of sludge solids is desired, Phase III is utilized to oxidize the sludge synthesized in Phases I or II during an extended aeration period so that the sludge accumulation approaches zero. Although this is called the total oxidation process, some excess sludge accumulates because of the inert solids fraction as well as the portion of the active solids which is resistant to oxidation. This residue may vary from 20 to 40 per cent of the total biological solids previously synthesized. The aeration period required to accomplish this auto-oxidation after conventional treatment is designated as D–E in Figure 11.

In some cases, the excess sludge produced during biological oxidation is separated and concentrated by sedimentation, and oxidized separately to economize on the size of the aeration tank required for this extended Phase III auto-oxidation.

Contact Stabilization

Another method of reducing capital costs of aeration tanks is the contact stabilization process which exploits the phenomenon of initial removal by biosorption. When the initial removal rate and its associated removable fraction are large, high BOD removals can be attained in short aeration contact periods resulting in a storage of appreciable quantities of BOD by the sludge solids. The sludge, with its stored BOD, is settled and is subsequently oxidized in separate, smaller tanks during a sludge aeration or stabilization period.

Increased substrate BOD removal can be obtained by increasing the aeration contact period, and when this increased time permits stored BOD to undergo assimilation, the sludge aeration or stabilization time can be reduced. When all the stored BOD is assimilated during the aeration period, the necessity for sludge reaeration is eliminated and the system approaches one of the processes described earlier.

In the treatment of domestic sewage, 93 per cent BOD reduction has been attained with contact periods of 0.24 hr and a sludge stabilization period of 1.6 hr; the mixed liquor suspended solids averaged 3,200 mg/l. BOD reductions of 86 per cent were obtained in the treatment of a mixture of textile wastes and domestic sewage with a contact period of 1.1 hr and a sludge stabilization period of 3.3 hr; aeration solids averaged 3,200 mg/l.

Summary

The performance of the activated sludge process has been defined in terms of BOD removal and sludge growth. It is recognized that variations in waste characteristics and changes in sludge condition will influence the parameters developed. These variations must be evaluated for each specific application.

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ASEIB EXAMINATIONS

The next qualifying examination of the American Sanitary Engineering Intersociety Board will be held on May 18, 1961. The examination will consist of three parts, one dealing with basic engineering sciences, a second dealing with the specialty area selected by the applicant, and the third, an oral examination. The areas of specialty recognized by the Board are: air pollution control, industrial hygiene, public health, radiation hygiene and hazard control, and water supply and wastewater disposal.

Application forms can be obtained by addressing: American Sanitary Engineering Intersociety Board, Inc., 33 West 39th Street, 15th Floor, New York 18.

For consideration of admission to the examination, applications must be received by April 1, 1961.

Sponsors are AIChE, APHA, ASCE, ASEE, AWWA, and WPCF.

DISSOLVED OXYGEN TITRATION ASSEMBLY

J. R. Malone

Two of the DO titration assemblies as shown in Figure 1 are in use in the sewage treatment plant laboratories of the Durham, N. C., Department of Water Resources. The units were put together from stock items of laboratory supply houses by personnel of the three jointly operated laboratories of the water and sewage treatment plants.

The burette has a 25-ml capacity with automatic zero adjustment and a three-way stopcock for quick filling. It is fastened to the support with thermometer clamps. The support is a standard large-sized rectangular base support with the hollow part of the base filled with several pounds of lead. The thiosulfate reservoir is a pyrex leveling bulb of 500 ml capacity; the starch reservoir is a 500-ml aspirator bottle; and the waste bottle is a plain bottle of about 150 ml capacity, all attached to the support rod by standard utility clamps. The thiosulfate reservoir is also supported in a split-type support ring so that it may be lowered for filling.

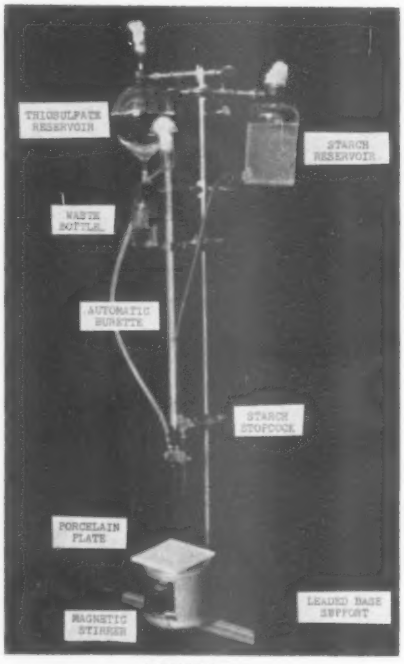


FIGURE 1.

The sample for titration is placed in a 400-ml beaker together with a plastic-sealed, magnetized-steel bar, and mixing is provided by this magnet moving with a revolving magnet in the stirrer upon which the beaker is placed. The porcelain plate is for easy detection of the change in color at the starch end point. Plastic tubing is used for carrying the thiosulfate solution from the reservoir to the burette. Starch solution that needs no refrigeration is used. Cotton plugs are considered sufficient to prevent air-borne contamination of the solutions in the reservoirs and burette.

J. R. Malone is Purification and Treatment Engineer in the Department of Water Resources, Durham, N. C.

OPERATION OF SEWAGE TREATMENT PLANTS

15. ACTIVATED SLUDGE

The activated sludge process is utilized to convert non-settleable substances, in finely divided, colloidal, and dissolved form, into settleable sludge and to remove this newly-formed sludge, thereby providing a high degree of treatment. The first action is accomplished in aeration tanks, while the second is accomplished in final settling tanks.

15.1 FUNDAMENTALS OF PROCESS

The activated sludge process depends on groups of microorganisms, primarily bacteria and protozoa living on sewage solids, as a purifying medium. These organisms are maintained in an aerobic environment by introducing air into a mixture of the activated sludge and sewage, after which the activated sludge is separated from the treated sewage by settling. The efficiency of sedimentation depends on the weight and density of the sludge developed. Settled activated sludge may then be reused to treat more sewage.

It is generally accepted that in the activated sludge process adsorption plays an important role in the removal of organic materials from sewage.

15.2 DESCRIPTION OF PROCESS

The process is a simple one. Settled or raw sewage is first mixed with activated sludge. Then the mixture flows into an aeration tank in which it is thoroughly mixed in the presence of dissolved oxygen for sufficient time to effect purification, and the resulting mixture passes into a settling tank in which the activated sludge is separated by gravity from the purified sewage. A portion of this settled activated sludge, termed return activated sludge, is then pumped back to aid in the purification of more sewage. Since the activated sludge is constantly increasing in quantity as it removes organic solids from the sewage, and as the microorganisms continually grow, it is necessary to remove the excess quantity from the system. The sludge so removed is termed waste activated sludge. The flow diagram in Figure 15-1 indicates the manner in which this process is carried out.

15.21 Basic Requirements

Obviously, the operation of so simple a process should not be difficult. It

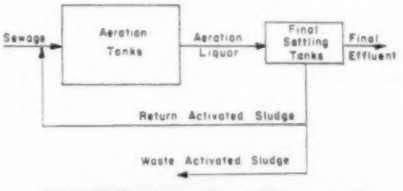


FIGURE 15-1.—Flow Diagram of Activated Sludge Process.

This is Chapter 15 of Operation of Sewage Treatment Plants, *Manual of Practice 11. Serialization of this manual began in the September 1960 issue.*

FIGURE 15-2.—Aeration tank.

need only meet the following three requirements:

1. The activated sludge should contain adequate numbers of purifying organisms;
2. Dissolved oxygen should be present in sufficient concentration in all portions of the aeration tanks; and
3. The activated sludge should separate readily from the treated sewage in the final settling tanks.

15.22 Development of Activated Sludge

The preparation of satisfactory activated sludge from the domestic sewage of a typical American city can be accomplished readily in a period of several days to two weeks, depending on the capacity of the aeration tanks. The only requisites are that dissolved oxygen be present in the aeration liquor, that the sludge settling in the final settling tanks be removed promptly, and that the aeration tanks be of sufficient capacity to provide an adequate time for purification to take place.

Despite the obvious simplicity of the process requirements, the practical application of the process is not so easily carried out. The particular problems arise from the varying nature of the purifying microorganisms, the constantly changing sewage characteristics, and the difficulty of maintaining a readily settleable sludge.

15.23 Aeration Tanks

15.231 Purpose:—The aeration tank (Figure 15-2) is the heart of the process. Here, oxygen is introduced to the system to satisfy the requirements of the activated sludge organisms and to keep the activated sludge dispersed in the aeration liquor. The tank capacity must be sufficient to provide enough retention time to accomplish the purification required.

15.232 Size:—There is no hard-and-fast theoretical size or retention period for aeration tanks. If the rate of introduction of dissolved oxygen is low, the period of retention must be relatively high. Conversely if dissolved oxygen is introduced at a high rate, the retention period in the tanks can be lower. Thus it is possible in one situation to require a retention period of as much as 12 hr and in another situation to accomplish the same degree of treatment in as little as 3 hr. In

both cases, the rate of solution of the oxygen is the determining factor.

15.233 Oxygen Supply:—Aeration tanks, by their design, limit the quantity of dissolved oxygen which can be put into solution in a given time. In every type of tank, there are two sources of oxygen that control the rate of its solution: (*a*) oxygen absorbed from diffused bubbles of air and entrained in the aeration liquor, and (*b*) oxygen adsorbed from the air above the tank surface.

15.234 Rate of Oxygen Solution:—The rate of solution of oxygen from the air bubbles in the liquid for a given aeration system depends largely on time of contact between bubble and the liquid and turbulence in the liquid. To extend this time of contact, the horizontal tank velocity from inlet to outlet should be low and the bubble path as long as possible. The liquid film in intimate contact with the bubble of air is saturated with oxygen almost immediately after the bubble is produced. The dissolved oxygen is then removed from this film into the adjoining liquid by diffusion, a very slow process. This diffusion may be increased in rate by the production of turbulent conditions in the liquid.

Absorption of dissolved oxygen from the air above the tank surface is proportional to the water surface area exposed to the air above it and to the rate of mixing of this saturated surface film with the body of the liquid. It is obvious that the quiet surface of a gently flowing stream creates a low rate of oxygen solution since both area and turbulence are at a minimum. By comparison, a body of water disturbed by choppy waves would expose more surface area to the air, have more mixing, and greater rates of solution of oxygen would result.

15.235 Types of Tanks:—It would appear that a minimum rate of oxygen solution would be found in an aeration tank of the stream-flow type, known in English practice as a Bioaeration plant, wherein all the oxygen is absorbed from the liquid surface only, and stirring is effected by paddles located in the tank. A plant of this type installed at Manchester, England, in 1935, has a retention period of 17 hr. With this long aeration period, it is capable of providing a high degree of treatment.

FIGURE 15-3.—Mechanical aeration device.

A brush-aeration tank of the type installed at Stockport, England, in 1938, utilizes largely surface aeration, with the production of a wavy tank surface by the mechanical action of a rotating stainless steel comb along an upper corner of tank surface. The increased rate of oxygen absorption compared with the Bioaeration process reduces the required retention period to about 7.5 hr for about the same degree of purification.

A third class of mechanical aeration facility introduces air in the body of the liquid in the aeration tanks by circulating the aeration liquor either by an updraft or downdraft pump (Figure 15-3). This action produces surface turbulence, at the same time diffusing air through the liquid mass. Aeration periods of about 8 hr are generally provided for effective purification.

The diffused air-type of aeration facility most commonly installed in recent years depends on the use of compressed air. The air is introduced near or at the bottom of the aeration tanks at multiple points through one of a rather wide variety of diffusers, including porous plates (Figure 15-4) and porous tubes (Figure 15-5) or jets.

FIGURE 15-4.—Porous plates in tank floor.

When diffused air is introduced in

FIGURE 15-5.—Swing-type porous-tubes diffuser.

spiral-flow or ridge-and-furrow aeration tanks, the tank liquids are kept in circulation by the air-lift effect. As the oxygen requirement is increased, more air must be used. This increases the air-lift effect producing an increase in the liquid velocity which in turn causes a decrease in bubble contact time. Thus as the oxygen requirement is increased, the bubble contact time is decreased, causing a lowering in the efficiency of utilization of the air introduced. These aeration tanks are generally designed for retention periods in the order of 5 hr.

15.24 Final Settling Tanks

15.241 Purpose:—The purpose of the final settling tanks is to bring about the separation of the activated sludge from the treated sewage. The mixture enters these tanks and is deflected toward the bottom by an influent baffle. The sludge separates rapidly and is moved to withdrawal points where it is removed continuously by the return sludge pumps. The effluent flows over weirs to be discharged into the effluent conduits.

15.242 Sludge Removal:—It is good practice to operate final settling tanks with as little depth of sludge on the bottom as possible. This can be accomplished by withdrawing the sludge at a rate such that its concentration of solids is the same as that of the sludge obtained from a sample of the mixed liquor after settling 30 min in a 1-l graduated cylinder (standard test).

Thus, if a 30-min sludge volume is 200 ml in a 1-l cylinder or 20 per cent, the quantity of return sludge drawn from the tank should be 20 per cent of the total flow of aeration liquor into the tank. This can be obtained easily where single tanks and meters are available; however, where more than one final settling tank is used, the control is rendered less effective by unequal distribution of flow into the tanks.

Where multiple settling tanks are used, it is sound practice to take soundings for sludge depth occasionally. Where excessive depths are noted, the rate of sludge withdrawal should be increased.

15.243 Settling Rates:—Rate of settling in these tanks is usually expressed in gallons of inflow per day per square foot of tank surface area (gpd/sq ft). Some use effluent rates but influent rates are more expressive of the effectiveness of a settling tank. Generally, effective settling inflow can be accomplished in well-designed tanks with rates of between 500 and 2,000 gpd/sq ft.

15.25 Sludge Reaeration

It is thought that two main actions take place in the activated sludge process: first, the removal of organic materials from the sewage by the sludge floc; and second, the aerobic digestion of the materials so removed by the microorganisms in the floc. These stages may be compared to the adsorption of alcohol vapors from fermentation gases. The vapors are passed through a bed of activated carbon and the alcohol is adsorbed on the carbon surfaces. When these surfaces are saturated no further adsorption takes place. The activated carbon is then reactivated by heating with steam, the alcohol being released, and the carbon bed is again able to treat more fermentor gas.

It is thought, similarly, that activated sludge adsorbs, on its large surface area, organic materials from the sewage being treated and that following this adsorption, the materials are converted to carbon dioxide and water and more activated sludge. In the ordinary activated sludge plant, both of these reactions are accomplished in the same aeration tank and are taking place, each in varying degree, throughout the aeration period. Reaeration is the separate aeration of the activated

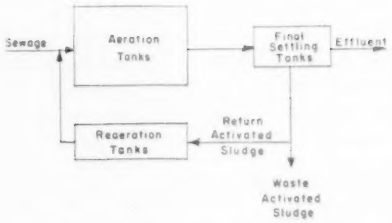


FIGURE 15-6.—Sludge reaeration flow diagram.

sludge in an aeration tank to effect this conversion.

The flow diagram in Figure 15-6 shows a conventional method of applying reaeration. The sludge as it returns from the final settling tank is aerated in a separate tank before it is added to the sewage to be purified. Thus the two major effects are accomplished, sewage purification in the aeration tanks and sludge reactivation in the reaeration tanks.

The principal advantage of reaeration in a separate tank is that it increases sludge stability and increases the capacity of the activated sludge system to take shock loads and recover quickly. The ability of an activated sludge system to resist changes, particularly as measured by the sludge index, depends on the quantity of sludge in the system. Reaeration in a separate tank also provides a good supply of seed sludge which might not be affected by a "slug" of toxic wastes passing through the plant for a period of slight duration.

It is possible to reaerate sludge at concentrations up to 20,000 mg/l without materially affecting the total air requirement. Reaeration does not seem to appreciably affect diffuser clogging.

Substantial quantities of process liquids such as digester supernatant liquor, vacuum filter effluent, and even small volumes of concentrated organic-type industrial wastes may be treated in the reaeration tanks without adversely affecting the activated sludge in the regular aeration tanks in any manner. Reaeration also provides a means of controlling the sludge index.

15.26 Air Cleaning

The air blown through diffusers must be clean if diffusers are to remain unclogged for substantial periods of time. The efficiency of air application is proportional to the pressure required to drive the air through the diffuser system; the higher the pressure, the greater the power required. The pressure at the blower is the total of the static liquid pressure over the diffusers, by reason of depth of the liquid, the pressure losses in the piping, and the pressure loss produced by forcing the air through the diffusers. The first two pressures are relatively fixed by system design, but the pressure loss in the diffusers increases as dust is deposited on the underside of and in the porous medium. From an operating standpoint, this loss should be kept to a minimum.

In areas where dust or smoke is a minor problem, cleaning the air is also a minor problem. Filtration of air

FIGURE 15-7.—Tank- and tube-cleaning accessories.

through paper filters, washing the air with water or oil, or impingement-type air cleaners will give fairly satisfactory results. Filters of these types remove the larger dust particles, but are ineffective for removal of fine particles which cause most of the clogging problems.

Where dust and smoke are present in high concentrations, the best type of air cleaning is required. Electrostatic dust precipitators in combination with bag filters or precoated bag filters are effective. Multiple filtration through cloth is also an efficient dust removal method. Dust removal equipment may be installed on either or both the suction and discharge of the blowers.

Diffuser cleaning (Figure 15-7) is a difficult operation at best. Cleaning methods such as treating with muriatic acid, chromic-sulfuric acid, caustic soda, spalling, and sand blasting can be used effectively. Any of these methods are costly both in labor and materials and should be avoided as much as possible by the installation of effective air filter equipment.

15.3 NORMAL OPERATION

15.31 Starting a New Plant

Before starting a new plant, it is important that all tanks and piping are free of debris, that all mechanical equipment is in good working order and properly lubricated, and that air filters, if available, are in place.

It is desirable to start treatment with about one-fourth to one-third of the incoming raw sewage flow, using only those portions of the plant needed to handle this flow. For example, one primary settling tank, one or two aeration tanks, and one final settling tank can be placed in service. The primary effluent feed should be increased slowly and the entire flow of raw sewage may be treated when the suspended solids concentration in the mixed liquor reaches between 500 and 800 mg/l. All the sludge settling in the final settling tanks must be returned promptly to the aeration tanks.

The quantity of air used must be sufficient to maintain dissolved oxygen in the mixed liquor. About 2 to 4 mg/l should be satisfactory. It is essential to provide sufficient agitation of the mixed liquor. Lack of it will permit the activated sludge to settle in the bottom of the aerators or in corners where it will become septic.

Normally, a good activated sludge will be produced within one to four weeks. The growth of the biological sludge mass is retarded in cold weather and accelerated in warmer weather. Hence, the prevailing air and sewage temperatures have a direct bearing on the time of development of a suitable floc.

15.32 Solids Concentrations to be Maintained

The quantity of activated sludge carried in the system should be as high as possible without impairing its settling quality or without depleting the dissolved oxygen in the aeration tanks. Ordinarily, the characteristics of the final settling tanks determine the quantity of activated sludge to be carried in the system.

It is first assumed that all of the sludge is in the aeration tanks and that as little as possible is kept in the final settling tanks. In Figure 15-1, letters may be assigned to the various rates of flow.

The average maximum rate of sewage flow over a 4-hr period may be represented by S and the rate of flow of the return sludge by R. The rate of flow of the aeration liquor should then be $R + S$. The amount of suspended solids in the aeration liquor that can be maintained as a maximum can be estimated as follows:

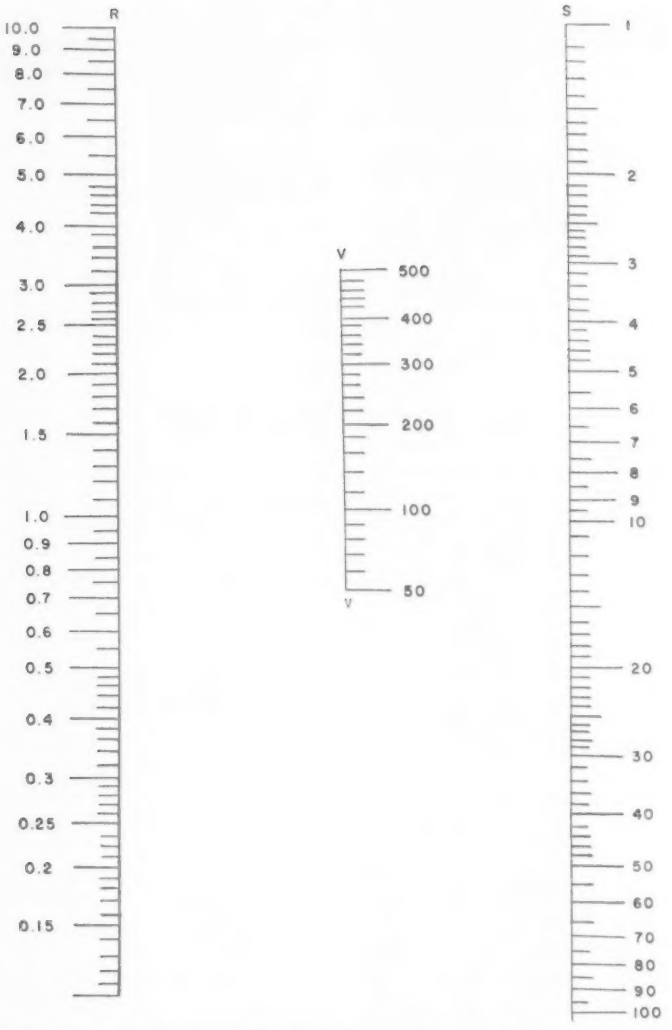


FIGURE 15-8.—Nomogram for determination of value of 30-min settling test.

$$\text{Sludge Volume (ml)}^* = \frac{R}{R+S} \times 1{,}000 \quad . . (1)$$

In the above generalization, it is assumed that the plant is well loaded. There are special cases, however, where the amount of air is limited, the loading is low, or the aeration period is long. With these conditions, it is desirable to operate the aeration tanks with a lower concentration of suspended solids in the aeration liquor. When this is the case, the rate of return sludge should be kept above the value given by the 30-min settling test formula or the values given in Figure 15-8. Thus, if it were found that

* Result of 30-min settling test in 1-l cylinder.

limited aeration prevented the settling test to exceed half that provided by the formula, the rate of flow or return sludge should not be reduced to half, but should be reduced to three-fourths.

The nomogram (Figure 15-8) may be used to solve this formula by drawing a straight line between the values of R and S and reading the value of the 30-min settling test at its intersection with Line V.

15.33 Control

Having arrived at a value for the maximum settling test value as above, the rate of flow of the waste activated sludge should be adjusted to keep the test result between the computed value and 30 less than that value. Thus, if the computed maximum settling test value is 230, keep the sludge volume after 30 minutes' settling between 230 and 200.

Where this control is not feasible, the level of sludge blanket in the final settling tanks can be used as a guide to sludge wasting. The level generally should not exceed one foot above the tank bottom.

In some cases, where activated sludge is wasted to the primary settling tanks, it is desirable to waste the sludge during periods of lowest sewage flow rates. This tends to improve the quality of the effluent from the primary settling tanks.

The quantity of sludge in the aeration tanks is determined and controlled as above by the 30-min settling test. To determine the desirable value of the corresponding aeration liquor suspended solids, it is necessary to know the value of the sludge density index. The index is equal to the weight in grams of 1 ml of sludge after 30 minutes' settling. The method for determining this value is found in "Standard Methods" (1). In the following discussion, it will be called the sludge index.

The nomogram (Figure 15-9) enables the computation of the sludge index by drawing a line between the settling test result, V, and the suspended solids result, A, and reading the sludge index, I, at its intersection with Line I. Likewise, given the sludge index and the settling test, the suspended solids can be determined.

Since the volume of sludge that can be settled in a liter settling test is known, and the sludge index which relates volume to weight can be determined, the computation of the maximum suspended solids which should be maintained in the aeration tank effluent can be made. The volume of sludge that should not be exceeded in the bottom of the liter settling test after 30 minutes is $\frac{R \times 1{,}000}{S + R}$, and if the sludge index is known, the grams of dry solids in the liter graduate may be found by multiplying the value of $\frac{R \times 1{,}000}{S + R}$ by $\frac{I}{100}$. This result is the maximum permissible grams of dry activated sludge solids in each liter of aeration liquor. To express the grams per liter found above in milligrams per liter, multiply by 1,000.

Note that the above refers to the *maximum* suspended solids concentration. Lower values can often be justified.

For example, if a plant has a maximum sewage flow rate of 1.0 mgd and a maximum return sludge rate of 0.4 mgd, and the sludge index is 1.1, what maximum suspended solids concentration can be maintained in the aeration tank effluent?

The maximum allowable volume of sludge in a liter settling test after 30 minutes is:

$$\frac{0.4}{1.0 + 0.4} \times 1{,}000 = 286 \text{ ml}$$

The suspended solids in the aeration tank effluent is:

$$286 \times \frac{1.1}{100} \times 1{,}000 = 3{,}146 \text{ mg/l}$$

FIGURE 15-9.—Nomogram for determination of sludge density index.

Note that while the arithmetic is carried to four places, in actual practice this number may be thought of as considerably less accurate. For all practical purposes, ± 5 per cent for aeration liquor solids control is excellent operation. Therefore, maintaining the solids level between 3,000 and 3,300 mg/l in this particular problem is satisfactory. Figure 15-10 indicates graphically the above relationship.

It is not necessary to carry the aeration liquor suspended at the highest possible level, since in most cases purification can be carried out to substantially the same degree at lower concentrations. There are, however, other reasons for carrying the solids at as high a level as possible. High aeration liquor suspended solids decrease the tendency for the sludge to bulk and reduce the frothing nuisance in the aeration tanks. Furthermore, the larger amount of activated sludge in

the system, the less will be the effect of shock loads or inhibiting substances. If one examines the above arithmetic, it becomes evident that as the sludge index decreases, the maximum allowable suspended solids in the aeration liquor decreases.

15.34 Dissolved Oxygen in Aeration Tank Liquor

15.341 Factors Controlling DO:—The maintenance of dissolved oxygen in a given design of aeration tanks depends on the following factors:

1. Quantity of air diffused and absorbed in the aeration tank liquor,
2. Retention period in the aeration tanks,
3. Strength of sewage, and
4. Concentration and character of the activated sludge in the aeration liquor.

15.342 Optimum DO Concentration:—Keep the concentration of dissolved oxygen in the aeration tank effluent between 3 and 5 mg/l when tests are taken only once each day, or above 1 mg/l and below 5 mg/l if tests are taken every 4 hr. The steps that may be taken to obtain this control follow:

With diffused-air aerators:

1. Increase air discharge by:
   (*a*) Increasing the blower speed, or
   (*b*) Starting an additional blower.
2. Decrease sewage rate of flow by:
   (*a*) Placing more aeration tanks in operation,
   (*b*) Increasing the flow rate through some of the tanks so that the rate of flow through the others is low enough to keep the dissolved oxygen concentration at a proper level, or
   (*c*) Bypassing part of the aeration tank influent to the receiving stream. (*This procedure is undesirable and should be used only as a last resort.*)

With mechanical aerators:

1. Increase the speed of mechanical device, if possible,
2. Place more aerators in service, or
3. Bypass part of aeration tank influent to the disposal stream, *if permissible.*

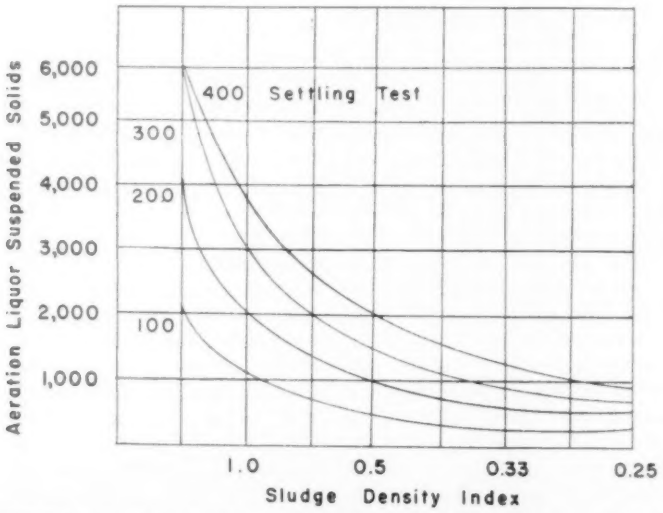


FIGURE 15–10.—Aeration liquor suspended solids—sludge index relationships.

15.4 OPERATION TROUBLES

15.41 Symptom A—Sludge Index Changes

Activated sludge is not a definite material, but rather a class of materials. Its specific properties are not constant due to the varying nature of the materials it is required to purify and to the different conditions to which it is subjected. Because of these variations, the sludge index changes from time to time.

15.411 Cause:—When inert materials of high density, such as finely divided clay or solids of high ash content, are added, the sludge index increases. When high organic loads, particularly of the dissolved variety, are added, the index decreases. Increasing indexes indicate that the sludge is more settleable and usually is not accompanied by problems in plant operation. Conditions causing decreasing indexes, however, can create serious problems of sludge handling which may be sufficiently severe to cause the failure of the final settling tanks to separate the sludge from the treated sewage. When the index decreases sufficiently to interfere with the process, the sludge is said to be "bulking."

15.412 Prevention and Cure:—

1. It has been demonstrated that as the sludge index decreases, it is necessary to decrease the aeration liquor suspended solids. It has been pointed out that the volume of the sludge is largely due to the microbiological growths. When the sludge index decreases, the change is brought about by an increase in this jelly-like material. Assume, that due to certain conditions, with 2,000 mg/l aeration liquor suspended solids, the volume of this growth increases so that the sludge index changes from 1.0 to 0.5. This means that the weight of sludge in the aeration tanks must be reduced to one-half its former value or to 1,000 mg/l suspended solids if the same volume of sludge is to be handled. Normally, however, the tendency for rapid increase in the volume of the jelly-like microbiological growth is reduced when the aeration liquor solids are at a high level. It would appear, therefore, that as large an amount of activated sludge solids as possible should be maintained consistent with the ability of the aeration facilities to provide dissolved oxygen and with the ability of the return activated sludge facilities to remove sludge from the final settling tanks.

2. Bulking of activated sludge may be controlled by the judicious application of chlorine to return sludge. The dosages generally found effective are 10 to 20 mg/l on the basis of volume of return sludge. A more satisfactory way of dosing and expressing the results would be on the basis of dry solids in the return sludge. On this basis, effective dosages of chlorine have been found to be 0.3 to 0.6 per cent of dry return sludge.

The effect of chlorine in the control of bulking has been attributed to a number of causes. It now appears that it has the power of forcing out the tenaciously held water associated with jelly-like material in the activated sludge. The application of chlorine for the control of bulking does not cure the causes of the phenomenon and is effective as long as chlorine is applied. If the causes are not removed, bulking will soon recur after the cessation of chlorination.

3. A process has been developed for the control of the sludge index by converting digested sludge to activated sludge. This sludge is then introduced into the normal activated sludge system. The principle of increasing the sludge index in this process involves the addition of digested sludge having a sludge index of 5 to 3.3 to part of the activated sludge, aerating the mix-

ture for a proper period of time, and introducing the activated sludge so formed into the normal return activated sludge to the aeration tanks. The increase in sludge index is proportional to the amount of digested sludge added when expressed in terms of dry solids.

15.42 Symptom B—Rising Sludge

15.421 Cause:—This is possibly due to excessive nitrification. There are two disadvantages to the production of nitrates and nitrites in the activated sludge process. The first, and most objectionable from the standpoint of plant operation, is the formation of rising sludge in the final settling tanks. If an aeration tank liquor containing nitrates is allowed to settle in a glass cylinder for a period of several hours, the sludge may first settle to the bottom of the cylinder. Soon minute bubbles will appear in the sludge and, after a period of time, the entire sludge mass may rise to the surface of the liquid. This action is caused by the utilization by bacteria of the oxygen in the nitrates dissolved in the water with the resulting production of gaseous nitrogen and carbon dioxide. These bubbles of gas reduce the density of the sludge until part or all of the sludge floats to the surface. This action may take place in a final settling tank, particularly if an appreciable depth of sludge is allowed to accumulate in the tank. When sludge floats to the surface in a final settling tank, a large increase in the suspended solids is observed in the effluent leaving that tank.

The second undesirable effect brought about by nitrates and nitrites is the fertilizing effect these compounds have on aquatic plants. Plants may grow extensively in a stream that contains appreciable concentrations of these compounds, and after these plants die, the organic matter they contain may deplete the oxygen in the stream and cause obnoxious odors.

15.422 Prevention and Cure:—When floating sludge appears in quantity on the final settling tanks, the following steps may be taken to remedy the condition:

1. Increase the rate of return activated sludge pumping from the final settling tank. This reduces the depth of sludge on the tank floor and increases movement of sludge toward the sludge withdrawal lines.

2. Decrease the rate of flow of aeration liquor into the offending tank if the sludge depth cannot be reduced by increasing the return activated sludge withdrawal rate and if other tanks are available.

3. Increase the speed of the sludge-collecting mechanism in the final settling tanks. This increases the rate of removal of sludge, providing the sludge blanket is at a minimum.

4. Decrease the nitrification by reducing aeration, or lowering the retention period by taking some aerators out of service.

Either or both of these methods are effective. If the retention period is reduced, additional aeration probably will be needed in the aeration tanks remaining in service.

15.43 Symptom C—Frothing

15.431 Cause:—In recent years, since the advent of synthetic detergents, a considerable nuisance has been production of froth in aeration tanks (Figure 15-11). Froth tends to form on the side opposite to the aeration devices and accumulates until it flows over the walkways, making them slippery and hazardous while wet, and depositing grease and dirt after drying. Wind causes the froth to blow about the plant soiling structures and creating a health hazard for the plant workmen.

The quantity of froth formed has been observed to increase with the following:

FIGURE 15-11.—Froth-covered aeration tank.

1. Decrease in aeration liquor suspended solids,
2. Increase in aeration,
3. Increase in degree of purification of sewage,
4. Increase in atmospheric temperature.

15.432 Prevention and Cure:—

1. Use water, effluent, or clarified sewage sprays in the frothing areas. This method may be a satisfactory control, but is undesirable from the standpoint of wet walkways due to blowing of the droplets of spray, and if sewage effluents are used, a health hazard is introduced.

2. Apply defoamants in small quantities to the tank surface. Defoamants are active materials that remove the froth rapidly when applied in very small quantities. They are not effective over long periods of time, and repeated dosing, several times per hour, is necessary.

3. Increase aeration liquor suspended solids concentration. This is the most effective means of control. Unfortunately, it appears that the factor that controls the defrothing property is suspended solids concentration rather than settleable volume. For this method to be an effective control measure, it is necessary that the sludge density index be high.

15.5 LABORATORY CONTROL

15.51 Oxygen Determinations

15.511 Dissolved Oxygen:—Since dissolved oxygen must be maintained throughout the activated sludge system, this test should be made at least once each day during maximum load periods. Samples should be collected from the aeration tank, final settling tank, and return sludge system.

15.512 BOD:—The BOD of the final effluent, compared with that of the primary effluent, gives the best measure of secondary treatment efficiency. A high BOD removal accompanied by a low suspended solids removal may indicate bulking or rising sludge. The BOD of the primary effluent indicates the load being applied to the activated sludge process. This provides information to the operator upon which he may base decisions with regard to operational controls such as variations in compressed air application and aeration liquor solids concentrations. Tests for BOD should be made on composite samples daily and never less than twice weekly.

15.52 Solids Determinations

15.521 Suspended Solids:—Comparison of final effluent and primary effluent suspended solids provides an additional measure of secondary treatment efficiency. The suspended solids test results on mixed liquor are utilized in determining the sludge density index. This index is a very important tool in process control and should be determined each day to permit proper adjustments in these controls.

15.522 Settleable Solids:—The results of this test (30-min settling) are used in determining the sludge density index. The test should be performed each day, since it provides both technical control information and a rapid visual impression of the settleability of the activated sludge.

Reference

1. "Standard Methods for the Examination of Water and Wastewater." 11th Ed., Amer. Public Health Assn., New York, N. Y. (1960).

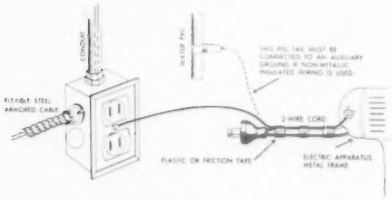
CORRECTIONS

In the paper, "Temperature and Feed as Variables in Activated Sludge Performance," by F. J. Ludzack, R. B. Schaffer, and M. B. Ettinger, published in the Journal in February 1961 (**33**, 2, 141), the authors have requested a correction. The following paragraph should be substituted for the second paragraph beginning with "Further comparison . . ." which is under the heading **Solids and Oxidation Relations**, page 153:

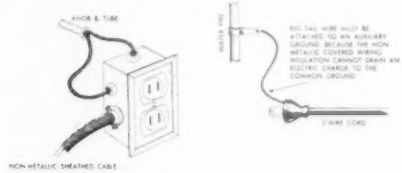
If it is assumed that the unit volatile solids gain consisted of materials having a similar oxygen demand, or COD as cell material, i.e., 1.4 g oxygen demand per gram, a crude estimate of process oxidation can be reached. The result is arbitrary because it is known that the basic assumption is not precisely followed. However, in Table I at 5°, about 0.4 g of unit volatile solids appeared per gram of influent oxygen demand. This represents 0.4×1.4, or 0.56 g of COD. The effluent contained about 0.3 g of COD. Then $0.56 + 0.30$ accounts for about 86 per cent of the influent demand, hence about 14 per cent should have been oxidized. Following the same manipulations, results in Table I at 30° represent 66-per cent oxidation. In Table V results show 41-per cent oxidation at 5°, 80-per cent oxidation at 30°. This substantiates Porges' (14) conclusion that temperature has a larger effect on oxidation than on removal. Likewise temperature effects on performance are not alike for all feeds.

TIPS AND QUIPS

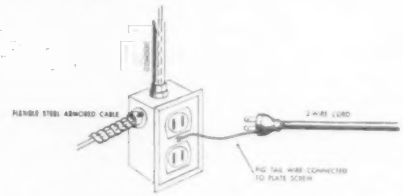
Five Ways to Ground Electrical Equipment *



1. To fit a conventional two-wire apparatus with a third ground wire, connect a 14 or 16 gage flexible copper wire to frame of the apparatus and dress wire along power cord to plug. Follow procedures indicated in the other illustrations, according to type of wiring in your home.

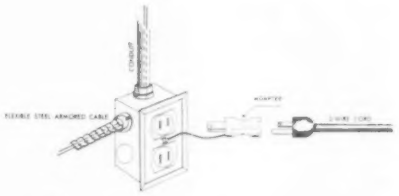


2. When the home is equipped with non-metallic cable or knob and tube installation, grounding is difficit. The pig tail of a three-wire plug or adaptor must be connected to an auxiliary ground—such as metal framework of buildings or water-well casings which lead to the earth. *Never* use gas pipes. When no such ground is available, install ground rods, plates, strips, or other units meeting National Electrical Code requirements.

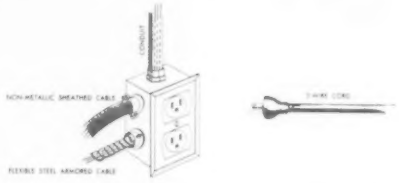


3. You can ground a three-wire electrical apparatus used with a conventional two-wire conduit or armored cable wiring system by plugging the pig tail from the three-wire plug to the receptacle plate screw.

* From *Home Safety Review*, fall 1960.



4. You can adapt a three-prong plug to a conventional two-wire conduit or armored cable wiring installation by fastening the pig tail of the adaptor to receptacle plate screw. Such an adaptor can be purchased.



5. This is the ideal method of home wiring. With three-wire installation throughout the home, you are protected from shock. The third wire drains all potential electric shocks to a common ground.

Smog

In a superb little pamphlet, the Air Pollution Foundation, 2556 Mission St., San Marino, Calif., discusses "Air Pollution and Smog" in understandable language.

The Los Angeles smog, for example, is caused by a chemical reaction that takes place when auto exhaust is exposed to the ultraviolet light from the sun. The exhaust ingredients which participate in this reaction are nitrogen oxides and olefinic hydrocarbons.

Surpisingly, perhaps, the black smoke emanating from diesel engines in trucks and buses does not contribute significantly to the formation of Los Angeles–type smog.

The London, St. Louis, and Pittsburgh smogs are something else again. They are characterized by a high content of sulfur compounds and particulate matter, and by a reducing effect on chemical reagents; Los Angeles smog is characterized by its high content of ozone, organic matter, and nitrogen oxides, and by its oxidizing effect on chemical reagents.

Moreover, London-type smog occurs at night, or on cold foggy days, with the temperature below 50°F; Los Angeles-type smog occurs chiefly in the middle of hot, sunny days, with the temperature usually in the range of 75 to 90°F.

Construction Forecast

The brightest spot on the economic horizon in 1961 will be construction, according to the annual outlook statement by F. W. Dodge Corporation. In fact, Dodge economists expect that construction contracts will show a slight increase next year, despite an expected mild dip in general business activity.

The construction industry as a whole is not likely to be adversely affected by the expected business dip, the Dodge analysis indicated. Some segments of construction, particularly those involving business spending, may go down next year, but public projects, which account for more than a third of the total, should show strength. In addition, easier money should help the housing sector, at least to the extent of preventing any further decline.

The outlook statement indicates that total construction contracts in 1961 will amount to some $35.8 billion, a gain of 1 per cent over the estimated 1960 level, and the second highest figure on record.

Most of the strength in 1961 is expected in contracts for heavy engineering construction, that is, public works and utilities. Heavy engineering contracts next year are forecast to total $8.9 billion, a gain of 5 per cent over 1960. Highway construction, which accounts for about half of all heavy engineering construction, is expected to set the pace in this category, backed up by strength in utility construction as well.

Residential building contracts, by far the largest major construction category, are expected to be up about 1 per cent next year, totaling some $15.3 billion.

Total private and public non-farm housing starts in 1961 are estimated at 1,325,000, a gain of 2 per cent over the 1960 estimated level of 1,300,000 on the current Census Bureau basis of measurement.

The report, published in the November issue of *Architectural Record*, stated that there is some evidence that the backlog of housing demand is not as strong as it has been in the past, and that, while easier money will undoubtedly have some upward effect in 1961, it may not be anywhere near as great as in previous recessionary periods.

Non-residential building contracts are expected to drop 2 per cent in 1961 to $11.6 billion, principally because of a falling off in business spending for new industrial and commercial building offsetting gains in some of the other non-residential building types.

On balance, the report says, "construction contracts should move upward a little in 1961, ending the brief decline of 1960. The industry may well be resuming its upward course, paralleling the growth of the nation and the economy to be expected during the much-heralded and currently overdiscounted Sixties."

It is the duty of every man to protect himself and those associated with him from accidents which may result in injury or death.

ABRAHAM LINCOLN

Water Pollution Control Federation

Yearbook
and
Supplementary Directory

1961

OFFICERS

PAST PRESIDENTS

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WATER POLLUTION CONTROL FEDERATION

4435 Wisconsin Avenue, Washington 16, D. C.

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Vice-President: Harry E. Schlenz

Treasurer: A. H. Niles

Executive Secretary-Editor: R. E. Fuhrman

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A. H. Niles 1949–50	Mark D. Hollis 1959–60

HONORS AND AWARDS

Honorary Members

The qualifications for Honorary membership in the Federation are set forth in Article II, Section 4 of the Bylaws. Honorary Members are elected upon recommendation of a committee comprising the President and four latest Past Presidents, the senior Past President as chairman, in accordance with a policy adopted by the Board of Control on October 23, 1943. Honorary Members elected to date are as follows:

*Charles Alvin Emerson 1941	Albert Edward Berry 1954
*Arthur S. Bedell 1942	*William Thomas Lockett 1954
*Julius W. Bugbee 1942	Gordon Maskew Fair 1955
*Langdon Pearse 1942	William H. Wisely 1956
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F. Wellington Gilcreas 1948	Francis S. Friel 1959
Wilford Willis DeBerard 1950	Arthur H. Niles 1960
Karl Imhoff 1953	*Renville S. Rankin 1960
Harold Warner Streeter 1953	

The Harrison Prescott Eddy Medal

The Harrison Prescott Eddy Medal is awarded annually to a member of any Member Association of the Federation for outstanding research contributing in important degree to the existing knowledge of the fundamental principles or processes of sewage treatment, as comprehensively described and published during any stated year in the Federation Journal. The award commemorates Harrison Prescott Eddy, a famous engineer and a pioneer in the art of sewage treatment.

* Deceased.

Past recipients of the award are:

Harry Willard Gehm 1943
John Raymond Snell 1944
Lloyd R. Setter 1945
H. Heukelekian 1946
Richard Pomeroy and Fred D. Bowlus 1947
F. W. Kittrell and O. W. Kochtitzky, Jr. 1948
John W. Hood 1949
Daniel A. Okun 1950
Peter S. S. Dawson and Samuel H. Jenkins 1951
George S. Benton, John C. Geyer, Wen-Hsiung Li, and Knut K. Sorteberg 1952
Donald M. Pierce 1953
William J. Oswald, Harold B. Gotaas, Harvey F. Ludwig, and Victoria Lynch 1954
William J. Katz, William L. Lea, and Gerard A. Rohlich 1955
G. J. Schroepfer, W. J. Fullen, A. S. Johnson, N. R. Ziemke, and J. J. Anderson 1956
W. N. Grune, J. V. Carter, Jr., and J. P. Keenan 1957
W. E. Budd and George F. Lambeth 1958
Edward R. Hermann and Earnest F. Gloyna 1959
P. H. McGauhey and Stephen A. Klein 1960

The George Bradley Gascoigne Medal

The George Bradley Gascoigne Medal is awarded annually to a member of any Member Association of the Federation for outstanding contribution to the art of sewage treatment works operation through the successful solution of important and complicated operational problems, as comprehensively described and published during any stated year in the Federation Journal. This award is in memory of George Bradley Gascoigne, a prominent consultant from 1922 to 1940, who demonstrated an unusual interest in matters of sewage works operation.

Past recipients of this award are:

Kerwin L. Mick 1943
James T. Lynch and Uhl T. Mann ...1944
John D. McDonald 1945
LeRoy Winfield Van Kleeck 1946
Leon S. Kraus 1947
David P. Backmeyer 1948
Wilbur N. Torpey 1949
Clarence E. Keefer 1950
Leonard S. Hillis 1951
Walter Asa Sperry 1952
W. N. Wells and Clarence H. Scherer 1953
Robert Ditmar Bargman 1954
Abraham H. Chasick 1955
Henry R. King 1956
T. T. Hay 1957
Dean M. Taylor 1958
Robert D. Bargman, William F. Garber, and Joe Nagano 1959
Cecil D. Parker, Harold L. Jones, and Neil C. Greene 1960

The Charles Alvin Emerson Medal

The Charles Alvin Emerson Medal is awarded annually to a member of any Member Association of the Federation "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Water Pollution Control Federation in such terms as the stimulation of membership, improving standards of operational accomplishments, fostering fundamental research, etc." This award honors Charles Alvin Emerson, who served as President of the Federation from 1928 to 1941 and became its first Honorary Member.

Past recipients are:

*Floyd William Mohlman 1943
*Willem Rudolfs 1944
Harold Warner Streeter 1945
F. Wellington Gilcreas 1946
*Langdon Pearse 1947
LeRoy Winfield Van Kleeck 1948
William J. Orchard 1949
Morris M. Cohn 1950
*Howard Eugene Moses 1951
*Frank Woodbury Jones 1952
William D. Hatfield 1953
*Charles C. Ruchhoft 1954
Merle Starr Nichols 1955
E. Sherman Chase 1956
Earnest Boyce 1957
Gail P. Edwards 1958
Albert E. Berry 1959
Frederick H. Waring 1960

* Deceased.

The Industrial Wastes Medal

The Industrial Wastes Medal was established in 1949 to be awarded annually in the form of a plaque to a member of any Member Association of the Federation for the most outstanding contribution by an industrial employee on any aspect of industrial wastes control, as published in the Federation Journal during the year preceding the award.

Past recipients are:

Roy F. Weston, Robert G. Merman, and Joseph G. DeMann 1950
Bruce W. Dickerson 1951
Robert J. Austin, Roy N. Giles, C. T. Nicholson, and F. W. Scheineman 1952
Richard H. Coe 1953
*N. H. Sanborn 1954
Kenneth S. Watson 1955
Charles R. Griffith 1956
F. E. Dryden, P. A. Barrett, J. C. Kissinger, and W. W. Eckenfelder 1957
H. W. Bialkowsky and P. S. Billington 1958
Roy H. Souther and Thomas A. Alspaugh 1959
T. W. Beak, Claude de Courval, and Norman E. Cooke 1960

The Kenneth Allen Award

From 1943 through 1948, meritorious personal service to Member Associations was recognized by the Kenneth Allen Award. The award was retired in 1948.

Recipients of this award have been:

1943

William Homer Wisely (Cen. St.)
*John Kurtz Hoskins (Fed.)
Harry Thornton Calvert (ISP)
Alfred Henry Weiters (Iowa)
Edward F. Eldridge (Mich.)
Edward P. Molitor (N.J.)
Robert S. Phillips (N.C.)
Fred Merryfield (Pac. N.W.)

1944

Leon Benedict Reynolds (Calif.)
Albert Edward Berry (Can.)
Wilson Waldo Towne (Dak.)
Van Porter Enloe (Ga.)
Albert Legrand Genter (Md.-Del.)
F. Wellington Gilcreas (N. Eng.)
Charles A. Holmquist (N.Y.)
Dana Ewart Kepner (Rky. Mtn.)

1945

Dario Travaini (Ariz.)
Joe Williamson, Jr. (Fla.)
Murray Alderson Wilson (Kans.)
George S. Russell (Mo.)
Frederick Holman Waring (Ohio)
*Howard Eugene Moses (Pa.)

1946

George W. Martin (Cen. St.)
Frank E. DeMartini (Fed.)
John Henry Garner (ISP)
Theodore R. Lovell (Iowa)
Thomas J. Doyle (Mich.)
John R. Downes (N.J.)
Harold Benedict Gotaas (N.C.)
William P. Hughes (Pac. N.W.)
E. J. M. Berg (Tex.)

1947

William T. Knowlton (Calif.)
William Storrie (Can.)
Floyd W. Pinney (Dak.)
Gilbert R. Frith (Ga.)
Clarence E. Keefer (Md.-Del.)
William Merriman Cobleigh (Mont.)
*Stuart E. Coburn (N. Eng.)
Wellington Donaldson (N.Y.)
Henry J. Darcey (Okla.)
Carroll H. Coberly (Rky. Mtn.)

1948

George W. Marx (Ariz.)
David Bryon Lee (Fla.)
William Q. Kehr (Mo.)
F. Dean Stewart (Ohio)
Francis S. Friel (Pa.)

* Deceased.

The Arthur Sidney Bedell Award

Established in 1948, the Arthur Sidney Bedell Award acknowledges extraordinary personal service to the Member Associations of the Federation. Each Member Association is privileged to name one of its members to receive the award, which may be earned by organizational leadership, administrative service, membership activity, stimulation of technical functions, or similar participation. The frequency of nomination varies from annually to once in three years, depending on membership. The award is named for the second President of the Federation, who exemplified its purpose by his long devotion and contribution to the affairs of the New York Sewage and Industrial Wastes Association.

Past recipients follow:

1949

Frederick Leon McDonald (Ark.)
Walter Asa Sperry (Cen. St.)
Harold Warner Streeter (Fed.)
*William Thomas Lockett (ISP)
John L. Strelow (Iowa)
*R. Paul Farrell (Ky.-Tenn.)
Harry P. Croft (N.J.)
*William McKinney Piatt (N.C.)
Carl Edwin Green (Pac. N.W.)
*Victor Marcus Ehlers (Tex.)

1950

Edward Alexander Reinke (Calif.)
Theodore J. Lafreniere (Can.)
Leland Bradney (Dak.)
William Hugh Weir (Ga.)
Abel Wolman (Md.-Del.)
Herbert B. Foote (Mont.)
LeRoy Winfield Van Kleeck (N. Eng.)
John Chester Brigham (N.Y.)
Frank S. Taylor (Okla.)
Leonard Oliver Williams, Jr. (Rky. Mtn.)
*L. L. Hedgepeth (Va.)
Robert G. McCall (W. Va.)

1951

John Clinton Clark (Ala.)
Harold W. Yost (Ariz.)
John Robertson Hoy (Fla.)
Charles Henry Trusler (ISE)
Roy Binder (Kans.)
Francis M. Veatch (Mo.)
Arthur H. Niles (Ohio)
*John Raymund Hoffert (Pa.)

1952

Harrison Hale (Ark.)
Don E. Bloodgood (Cen. St.)
Walter F. Freeborn (ISP)
Paul Bolton (Iowa)
Francis W. Kittrell (Ky.-Tenn.)
Clarence Theodore Mudgett (Mich.)
P. N. Daniels (N.J.)
Herman Glenn Baity (N.C.)
Ray E. Koon (Pac. N.W.)
George Ashby Rhame (S.C.)
Winfred S. Mahlie (Tex.)

1953

Arthur T. Wintersgill (Calif.)
Douglas L. McLean (Can.)
John B. Kleven (Dak.)
Nathan M. deJarnette (Ga.)
Ralph E. Fuhrman (Md.-Del.)
Fred F. Palmer (Mont.)
Walter E. Merrill (N. Eng.)
Anthony J. Fischer (N.Y.)
Quintin B. Graves (Okla.)
Robert James Auld (P.R.)
Charles G. Caldwell (Rky. Mtn.)
Eugene C. Meredith (Va.)
Henry W. Speiden (W. Va.)

* Deceased.

1954

Arthur N. Beck (Ala.)
Merle V. Ellis (Ariz.)
John W. Wakefield (Fla.)
Max Prüss (Germany)
Gilbert T. Cotterell (ISE)
Leland A. Talbot (Kans.)
°Charles A. Haskins (Mo.)
Theodore C. Schaetzle (Ohio)
Bernard S. Bush (Pa.)
Arnold Hoerler (Swiss)

1955

C. H. French (Ark.)
Frederick G. Nelson (Calif.)
George J. Schroepfer (Cen. St.)
Carl E. Schwob (Fed.)
Leo Holtkamp (Iowa)
F. T. Hambleton (ISP)
Herman D. Regan (Ky.-Tenn.)
James L. Love (La.)
Thomas J. Powers (Mich.)
William F. Rapp (Nebr.)
Henry Van Der Vliet (N.J.)
R. C. Sweeney (N.Y.)
P. D. Davis (N.C.)
Emil C. Jensen (Pac. N.W.)
T. R. Haseltine (Pa.)
W. T. Linton (S.C.)
Nils Westberg (Sweden)
J. H. Sorrels (Tex.)

1956

Arthur G. Pickett (Calif.)
Ray J. Desmarais (Can.)
W. W. Mathews (Cen. St.)
John E. Kiker, Jr. (Fla.)
Charles E. Drummond, Jr. (Ga.)
W. McLean Bingley (Md.-Del.)
Rodney Preator (Mont.)
Steven M. Hurley, Jr. (N. Eng.)
°Earl Devendorf (N.Y.)
Bruce M. McDill (Ohio)
William J. Bishop (Okla.)
C. H. Young (Pa.)
Luis Ramos Robles (P. R.)
Richard Messer (Va.)
Harry K. Gidley (W. Va.)

1957

Joseph L. Crockett (Ala.)
Leigh Owen Gardner (Ariz.)
Alvin A. Appel (Calif.)
Gordon Henry Baker (Can.)
O. J. Muegge (Cen. St.)
David B. Smith (Fla.)
Friedrich Wilhelm Sierp (Germany)
Myron K. Nelson (Kans.)
Robert A. Greene (Mich.)
Lindon J. Murphy (Mo.)
Henry F. Munroe (N. Eng.)
Louis J. Fontenelli (N.J.)
°Raymond W. Hess (N.Y.)
Carl D. McGuire (Ohio)
Robert O. Sylvester (Pac. N.W.)
Howard T. Reuning (Pa.)

1958

C. W. Oxford (Ark.)
Raymond R. Ribal (Calif.)
Clarence S. Anderson (Can.)
C. C. Larson (Cen. St.)
Ralph H. Baker, Jr. (Fla.)
F. W. Allen (ISP)
H. S. Smith (Iowa)
S. Leary Jones (Ky.-Tenn.)
A. J. Szabo (La.)
Donald M. Pierce (Mich.)
Victor J. Lechtenberg (Nebr.)
Robert S. Shaw (N.J.)
Uhl T. Mann (N.Y.)
George S. Rawlins (N.C.)
Kenneth H. Spies (Pac. N.W.)
Roy F. Weston (Pa.)
T. E. Robertson (S.C.)
Elof Ljungholm (Sweden)
Roger Moehlman (Tex.)

° Deceased.

1959

Richard Pomeroy (Calif.)
William L. McFaul (Can.)
Kerwin L. Mick (Cen. St.)
Louis W. Veigel (Dak.)
Marion B. Nixon (Ga.)
A. J. Kaplovsky (Md.-Del.)
Harlan P. Dodge (Mich.)
Irving J. Staid (Mont.)
Walter M. Kunsch (N. Eng.)
A. F. Dappert (N.Y.)
W. D. Sheets (Ohio)
C. R. Holden (Okla.)
L. D. Matter (Pa.)
G. Flaque-Garces (P.R.)
R. P. Lowe (Rky. Mtn.)
C. H. Connell (Tex.)
Frank H. Miller (Va.)
Glen O. Fortney (W. Va.)

1960

C. L. Gray (Ala.)
Art F. Vondrick (Ariz.)
Sydney Preen (Calif.)
Antoine V. Delaporte (Can.)
Robert W. Frazier (Cen. St.)
M. E. Dawkins (Fla.)
Franz Schmitz-Lenders (Germany)
B. A. Poole (Ind.)
N. J. Tatman (IPHE)
James F. Aiken, Jr. (Kans.)
Jack E. Cooper (Mich.)
J. E. Johnston (Miss.)
Jack K. Smith (Mo.)
Earl R. Howard (N. Eng.)
Andrew Palmer (N.J.)
C. E. Irving (N.Y.)
Ronald Hicks (New Zealand)
E. F. Wittmer (Ohio)
R. T. Smith (Pac. N.W.)
Harry W. McElhaney (Pa.)
André Kropf (Swiss)
Lynn M. Thatcher (Utah)

The William D. Hatfield Award

For the years 1946 through 1954, the William D. Hatfield Award recognized outstanding annual sewage works operation reports. After the first year, awards were made on the basis of plants serving (I) less than 10,000 population, (II) populations of 10,000 to 100,000, and (III) populations of more than 100,000.

This award was revised so that since 1956 it has been given for outstanding works operation. At that time, the frequency of this nomination was changed to correspond with the Bedell Award which is given each year, alternate years, or each third year, depending on the number of members within the Member Association.

Recipients of this award have been:

1946

Walter M. Kunsch

1947

F. E. Peterson (I)
John R. Szymanski (II)
Warren H. Sleeger and George J. Schroepfer (III)

1948

F. E. Peterson (I)
Thomas T. Hay (II)
Kerwin L. Mick (III)

1949

Russell D. Craun (I)
George W. Martin (II)
Thomas T. Hay (II)

1950

William L. Edwards (I)
Walter A. Sperry (II)
John R. Szymanski (II)
John W. Johnson (III)

1951

William L. Edwards (I)
J. E. Meers (II)
John R. Szymanski (II)
George H. Craemer (III)
Kerwin L. Mick (III)

1952–3; no award.

1954

Uhl T. Mann (II)
J. E. Meers (II)
C. W. Christenson (Indus.)

1955; no award.

1956

Murray B. McKinnie (Calif.)
I. G. Knoebel (Cen. St.)
Robert E. Simon (Fla.)
F. W. Crane (N.Y.)
Arthur D. Caster (Ohio)
Curtis L. Glenn (Okla.)
Robert Bolenius (Pa.)
A. F. Chamblin (Va.)
Gordon Remsburg (Md.-Del.)
George H. Craemer (N. Eng.)

1957

Owen D. Waldrep (Ala.)
Edward E. Bayze (Ariz.)
Edward O. Sampson (Calif.)
Douglas J. Davidson (Can.)
Ronald A. Kronewitter (Cen. St.)
Clifford M. Courson (Fla.)
Lyle Cunningham (Kans.)
J. C. Marshall (Mich.)
Walter C. Anderson (N. Eng.)
Anthony J. Macri (N.J.)
Uhl T. Mann (N.Y.)
Andrew J. Wahl (Pac. N.W.)
King H. Hendrickson (Pa.)

1958

Dan Millender (Ark.)
Melvin F. Klemmick (Calif.)
Charles Hicks (Can.)
Kerwin L. Mick (Cen. St.)
Daniel J. Raye (Fla.)
M. F. Neuzil (Iowa)
Walter T. Blackman, Sr. (Ky.-Tenn.)
Stanley J. Mogelnicki (Mich.)
Loren Brannen (Nebr.)
William S. Applegate (N.J.)
John O. Laird (N.Y.)
John L. Brown (N.C.)
Kenneth E. Mathews (Pac. N.W.)
Paul N. Longley (Pa.)
Frank M. Gibson (S.C.)
Carl Alm (Sweden)
S. L. Allison (Tex.)

1959

George E. Toole, Sr. (Calif.)
Frank I. Vilen (Cen. St.)
Chester O. Sherva (Dak.)
Leonard E. Waller (Ga.)
Hugh A. Schreiber (Md.-Del.)
C. Preston Witcher (Mich.)
Clarence V. Hickey (N. Eng.)
J. M. Brown, Jr. (N.Y.)
James H. Blodgett (Ohio)
John Mullins (Okla.)
G. H. Boone (Pa.)
Ruben A. Guzman (P.R.)
W. N. Wells (Tex.)
James Dooley (Va.)

1960

James L. Slovensky (Ala.)
E. O'Neal Dye (Ariz.)
William R. Teague (Calif.)
William Hardy (Can.)
D. A. Whitlock (Cen. St.)
George T. Lohmeyer (Fla.)
W. W. Mathews (Ind.)
V. W. Pickering (Kans.)
Lloyd B. Tompkins (Mich.)
Sidney C. Smith (Mo.)
Steven A. Stankey (N. Eng.)
Edward F. Lawler (N.J.)
F. J. Cramer (N.Y.)
Keith Davis (New Zealand)
T. C. Schaetzle (Ohio)
James R. Burns (Pac. N.W.)
Paul Cygan (Pa.)
Emil Meyer (Utah)

Membership Prizes

Prizes for membership activity in its various Member Associations have been awarded by the Federation since 1943. The numerical prize is given to the Member Association having the greatest numerical increase in membership during the year ending September 30 of the award year. The percentage prize is given for the greatest percentage increase in membership during the same period. The following Member Associations have received these prizes:

	Association			*Association*			*Association*	
Year	*Num.*	*%*	*Year*	*Num.*	*%*	*Year*	*Num.*	*%*
1943	Cen. St.	Fed.	1949	Ohio	Ala.	1955	Mich.	Ga.
1944	Cen. St.	Mo.	1950	Iowa	La.	1956	Cen. St.	Ky.-Tenn.
1945	Can.	Ariz.	1951	Mich.	ISE	1957	Fla.	Rky. Mtn.
1946	Can.	Okla.	1952	Cen. St.	Fla.	1958	Mich.	P. R.
1947	ISP	Ark.	1953	Calif.	P. R.	1959	Rky. Mtn.	Nebr.
1948	Pa.	W. Va.	1954	Pa.	P. R.	1960	Ind.	New Zealand

The Quarter Century Operators' Club

The Quarter Century Operators' Club is an informal group comprising Active or Corporate Members of any Member Association who had been engaged in sewage treatment works operation, on a full-time resident basis, twenty-five years prior to the date of their admission into the Club. The Club was created in 1941 under the sponsorship of Frank Woodbury Jones, who served as its first registrar. The present registrar is Henry Van Der Vliet.

Philip Artese
Harry M. Beaumont
Don E. Bloodgood
Floyd G. Browne
Raymond G. Case
Samuel Cenicola
E. Sherman Chase
Morris M. Cohn
John W. Collom
Rodney E. Cook
P. N. Daniels
Nicholas De Haas, Sr.
Joel Clifford Dillard
M. S. Fitzsimmons
George E. Flower
Louis J. Fontenelli
Harry M. Freeburn
E. D. Fry
G. L. Fugate
Ralph E. Fuhrman
Albert J. Gadomski
Arnold H. Goodman
Michael A. Groen
William P. Gyatt
C. Austin Habermehl
George A. Hall
Wm. C. Hamm
Herbert W. Hansen
George I. Hanson
T. R. Haseltine
William D. Hatfield
T. R. Komline
Harry J. Krum
William R. Lafferty
Roy S. Lanphear
Carl C. Larson
Harry C. Lewis
John V. Lewis
George S. Long
Winfield S. Mahlie
C. D. McGuire
Edwin C. McKeeman
E. F. Miltner
C. T. Mudgett
E. L. Nance
I. H. Nevitt
Arthur H. Niles
Andrew Palmer
John R. Palmer
Williard P. Pfeifer
Theodore C. Schaetzle
Glenn Searls
Willard R. Smith
Walter A. Sperry
H. W. Streeter
John Struss
Myron W. Tatlock
S. L. Tolman
John C. Truax
Henry Van Der Vliet
Edwin B. Wagner
Oscar Ward
W. W. Watmough
Gordon J. Weist
Charles E. Wheeler, Jr

ANNUAL MEETINGS AND CONVENTIONS

No.	*Location*	*Date*
1	Chicago, Ill.*	Oct. 16, 1928
2	New York, N. Y.*	Jan. 18, 1929
3	New York, N. Y.*	Jan. 14, 1930
4	New York, N. Y.*	Jan. 22, 1931
5	New York, N. Y.*	Jan. 22, 1932
6	New York, N. Y.*	Jan. 19, 1933
7	New York, N. Y.*	Jan. 18, 1934
8	New York, N. Y.*	Jan. 18, 1935
9	New York, N. Y.*	Jan. 16, 1936
10	New York, N. Y.*	Jan. 22, 1937
11	New York, N. Y.*	Jan. 21, 1938
12	New York, N. Y.*	Jan. 20, 1939
13	New York, N. Y.*	Jan. 18, 1940
	Chicago, Ill.†	Oct. 3–5, 1940
14	New York, N. Y.*	Jan. 15, 1941
	New York, N. Y.†	Oct. 9–11, 1941
15	Cleveland, Ohio	Oct. 22–24, 1942
16	Chicago, Ill.	Oct. 21–23, 1943
17	Pittsburgh, Pa.	Oct. 12–14, 1944
18	Chicago, Ill.*	Oct. 17–18, 1945
19	Toronto, Ont., Can.	Oct. 7–9, 1946
20	San Francisco, Calif.†	July 21–24, 1947
	Philadelphia, Pa.*	Oct. 10, 1947
21	Detroit, Mich.	Oct. 18–21, 1948
22	Boston, Mass.	Oct. 17–20, 1949
23	Washington, D. C.	Oct. 9–12, 1950
24	St. Paul, Minn.	Oct. 8–11, 1951
25	New York, N. Y.	Oct. 6–9, 1952
26	Miami, Fla.	Oct. 13–16, 1953
27	Cincinnati, Ohio	Oct. 11–14, 1954
28	Atlantic City, N. J.	Oct. 10–13, 1955
29	Los Angeles, Calif.	Oct. 8–11, 1956
30	Boston, Mass.	Oct. 7–10, 1957
31	Detroit, Mich.	Oct. 6–9, 1958
32	Dallas, Tex.	Oct. 12–15, 1959
33	Philadelphia, Pa.	Oct. 2–6, 1960

* Annual business meeting of Board of Control only.
† Convention of membership-at-large only.

DIRECTORY OF COMMITTEES

1960–61

CONSTITUTIONAL COMMITTEES

(See Article VI of Bylaws)

Executive Committee of the Board of Control

Ray E. Lawrence, *Chairman*

Harry E. Schlenz, *Vice-Chairman*

M. A. Churchill
W. A. Darby
M. D. Hollis
H. Harvey Hunt
A. J. Steffen

General Policy Committee

M. D. Hollis, *Chairman*

R. E. Lawrence, *Vice-Chairman*

J. J. Gilbert
W. D. Hatfield
K. S. Watson

Finance Committee

The Finance Committee develops the annual operating budget of the Federation and affords guidance to the Board of Control in financial affairs.

W. J. Orchard, *Chairman*

R. F. Orth, *Vice-Chairman*

M. D. Hollis
R. E. Lawrence
A. H. Niles

Publications and Program Committee

The Publications and Program Committee arranges the technical programs for the annual conventions of the Federation and has general supervision of all publications of the Federation.

George E. Symons, *Chairman*

Paul Haney, *Vice-Chairman*

C. S. Anderson
H. H. Black
D. Bloodgood
R. E. Fuhrman
J. B. Hanlon
E. R. Howard
E. Hurwitz
R. R. Kennedy
W. N. Konrad
C. C. Larson
D. B. Lee
L. F. Oeming
E. A. Pearson
G. Rohlich
W. W. Saxton
C. R. Walter
K. S. Watson
R. F. Weston

Organization Committee

The Organization Committee examines and reports to the Board on applications for membership in the Federation and endeavors to encourage the formation of new regional associations or conferences eligible for membership.

J. W. Wakefield, *Chairman*

B. A. Poole, *Vice-Chairman*

G. A. Howell
W. Q. Kehr
W. W. Saxton

Sewage and Industrial Wastes Practice Committee

The Sewage and Industrial Wastes Practice Committee reviews and directs for publication any resolution, report, or publication which establishes professional or technical standards in the name of the Federation. The following Manuals of Practice have been published under the direction of the Committee:

No. 1—Safety in Wastewater Works (1959)
No. 2—Utilization of Sewage Sludge as Fertilizer (1946)
No. 3—Municipal Sewer Ordinances (1949, Reprinted 1957)
No. 4—Chlorination of Sewage and Industrial Wastes (1951)
No. 5—Air Diffusion in Sewage Works (1952)
No. 6—Units of Expression for Wastes and Waste Treatment (1958)
No. 7—Sewer Maintenance (1960)
No. 8—Sewage Treatment Plant Design (1959)
No. 9—Design and Construction of Sanitary and Storm Sewers (1960)

Morris M. Cohn, *Chairman*

D. E. Bloodgood, *Vice-Chairman*

R. D. Bargman
J. F. Byrd
A. D. Caster
T. W. Clapham
E. A. Farmer
R. E. Fuhrman
M. S. Hilbert
E. R. Howard
C. E. Keefer
A. H. Niles
H. E. Orford
D. M. Pierce
M. L. Robins
L. W. Van Kleeck
F. M. Veatch
J. J. Wirts

Subcommittee on Sewer Maintenance

This Subcommittee has developed a Manual of Practice entitled "Sewer Maintenance." The manual was published in 1960.

T. W. Clapham, *Chairman*

A. A. Appel, *Vice-Chairman*

N. S. Bubbis
H. J. Graeser
M. B. Nixon
G. M. Olewiler
J. L. Klamm
Sydney Preen
L. E. West

Subcommittee on Standardization of Units

This Subcommittee of the Sewage and Industrial Wastes Practice Committee has been assigned to develop an approved schedule of units to be used in the reporting of plant operation and laboratory data. A committee of about forty members is engaged in revising a preliminary draft.

H. E. Orford, *Chairman*

Subcommittee on Trickling Filters

This Subcommittee of the Sewage and Industrial Wastes Practice Committee is engaged in the development of a Manual of Practice to be entitled "Trickling Filters—Their Characteristics and Loadings."

J. W. Kimm, *Chairman*

B. F. Hatch
Kenneth V. Hill
H. F. Seidel
Wm. E. Stanley
Graham Walton

Sewage and Industrial Wastes Practice Committee (Cont.)

Subcommittee on Paints and Protective Coatings

This Subcommittee has the function of assembling experience and data on paints and protective coatings used in sewage works, to be presented with recommendations in the form of a manual. The Subcommittee was created in 1946 and the first draft of the manual is now being prepared for critical review.

M. L. Robins, *Chairman*

Virgil Anderson	L. S. Kraus	F. W. Pinney
J. W. Johnson	K. L. Mick	Walter A. Sperry

Subcommittee on Vacuum Filtration of Sludge

This Subcommittee was created in 1951 for the purpose of developing a Manual of Practice on vacuum filtration of sewage sludge.

E. R. Howard, *Chairman*

E. B. Cobb	W. E. Stanley
J. D. McDonald	L. W. Van Kleeck

Subcommittee on Operation of Sewage Plants

This Subcommittee was created in 1953 for the purpose of developing a Manual of Practice on sewage plant operation.

D. M. Pierce, *Chairman*

A. P. Troemper, *Vice-Chairman*

W. M. Bingley	E. F. Eldridge	A. H. Niles
D. E. Bloodgood	R. E. Fuhrman	C. I. Sterling, Jr.
J. Crafts	G. E. Griffin	G. E. Symons
P. N. Daniels	L. S. Kraus	L. W. Van Kleeck

Industrial Wastes Manual Subcommittee

This Subcommittee was created in 1957 to review the availability of manuals from all sources concerning the treatment of industrial wastes and to determine the need for additional manuals, if any, that should be prepared by the Federation.

J. F. Byrd, *Chairman*

L. F. Birkel	C. W. Hathaway	G. M. Neas
R. M. Drummond		R. F. Rocheleau

Sewage Works Finance Subcommittee

This Subcommittee was created in 1957 to study the need for a manual on sewage works financing.

E. A. Farmer, *Chairman*

A. A. Estrada	G. Hauer	F. M. Veatch
Paul Haney	Roy Ritter	S. I. Zack
	Kenneth Spies	

Subcommittee on Sanitary and Storm Sewer Design

Since 1953 this Subcommittee has served jointly with representatives of the American Society of Civil Engineers to develop a Manual of Practice. The Manual, "Design and Construction of Sanitary and Storm Sewers," was published in 1960.

C. G. Gaither	L. L. Sphar	C. R. Velzy
H. S. Smith		S. I. Zack

Sewage and Industrial Wastes Practice Committee (Cont.)

Subcommittee on the Revision of Federation Manual of Practice No. 3

A. D. Caster, *Chairman*

F. H. Dobb
A. H. Niles
R. S. Phillips
D. F. Smallhorst
A. J. Steffen

Subcommittee on Sludge Digestion

This Subcommittee was created in 1958 to prepare a Manual of Practice on sludge digestion as applied to wastewater treatment.

R. D. Bargman, *Chairman*

C. B. Carpenter
W. F. Garber
W. N. Grune
R. H. Howe
R. R. Kennedy
M. F. Neuzil
W. A. O'Leary
E. S. Ordway
D. M. Pierce
R. H. Ritter
H. A. Schreiber
J. W. Townsend

Subcommittee on Fringe Area Sanitation

This Subcommittee was created in 1958 to study and prepare a Manual of Practice on wastewater collection and disposal problems of residential and commercial development in fringe areas of communities.

M. S. Hilbert, *Chairman*

C. F. Abel
S. A. Berkowitz
J. M. Coulter
M. C. Hope
R. J. Johnson
L. Kraus
H. F. Ludwig
E. H. Olsen
E. L. Stockton

Research Committee

The Research Committee has the function of stimulating research work among the various Member Associations, and of cooperating with other organizations in the promotion of research. The Committee makes an annual review of the literature on sewage, waste treatment, and water pollution.

H. Heukelekian, *Chairman*

R. Manganelli, *Vice-Chairman*

T. A. Alspaugh
E. J. Berg
H. F. Clark
C. H. Connell
W. E. Dobbins
G. P. Edwards
M. B. Ettinger
D. G. Foulke
T. D. Furman
P. Gaffney
I. Gellman
H. G. Harding
J. D. Helwig
R. D. Hoak
R. S. Ingols
W. M. Ingram
P. W. Kabler
M. Katz
F. W. Kittrell
N. J. Lardieri
H. G. Luley
P. H. McGauhey
R. Porges
A. J. Steffen
C. Straub
C. M. Tarzwell
G. H. Teletzke
W. W. Towne
H. A. Trebler
E. C. Tsivoglou
E. Weisberg
R. L. Woodward

Committee on Nominations

The special Nominating Committee was created by the Board of Control on October 9, 1946, to function in an advisory capacity to the Election Committee. The Nominating Committee is to comprise the last five living Past Presidents, with the senior Past President as chairman.

G. W. Martin, *Chairman*

E. C. Jensen, *Vice-Chairman*

W. D. Hatfield
M. D. Hollis
K. S. Watson

Committee on Standard Methods of Sewage and Industrial Wastes Analysis

Created by the Board of Control on January 22, 1931, the Committee on Standard Methods of Analysis was given constitutional status in October 1953. The Committee develops, perfects, and modifies standard methods for the analysis of sewage and industrial wastes and of sludges or by-products therefrom. It also functions with similar committees of the American Water Works Association and American Public Health Association in the production of the laboratory manual *Standard Methods for the Examination of Water and Wastewater*, the eleventh edition of which was published in 1960.

R. S. Ingols, *Chairman*

W. A. Moore, *Vice-Chairman*

D. E. Bloodgood
A. M. Buswell
C. J. Carney
W. A. Cawley
N. S. Chamberlin
G. Chanin
J. M. Cohen
M. Dannis
R. V. Day
G. P. Edwards
S. Faust
K. Fraschina
P. E. Gaffney
B. L. Goodman
C. F. Gurnham
W. D. Hatfield
W. L. Henderson
D. Hernandez
R. D. Hoak
E. F. Hurwitz
J. E. Kinney
R. R. Kountz
J. B. Lackey
J. C. Lamb, III
G. W. Lawton
K. M. Mackenthun
H. C. Marks
M. G. Mellon
G. B. Morgan
J. C. Morris
F. E. Nussberger
T. R. Ostrom
R. Pomeroy
M. C. Rand
M. L. Robins
G. A. Rohlich
W. W. Sanderson
K. L. Schulze
L. R. Setter
O. C. Sieverding
V. T. Stack, Jr.
C. M. Tarzwell
W. W. Ullmann
R. F. Weston

Industrial Wastes Committee

The Industrial Wastes Committee was created by the Board of Control on October 23, 1943, for the purpose of developing interest in this important field and to direct a program whereby the Federation may be of service in industrial waste problems.

K. S. Watson, *Chairman*

H. T. Reuning, *Vice-Chairman*

V. W. Bacon
E. B. Besselievre
H. H. Black
D. E. Bloodgood
J. F. Byrd
G. Chanin
H. F. Elkin
C. Fair
W. J. Fullen
Harry Gehm
C. F. Gurnham
R. J. Keating
Hugh Kline
Kerry Mills
S. J. Mogelnicki
L. F. Oeming
G. A. Pettit
R. E. Rostenbach
C. N. Sawyer
A. J. Steffen
R. F. Weston

SPECIAL COMMITTEES

Committee on Personnel Advancement

Authorized by the Board of Control on October 11, 1941, this Committee is assigned to "establish minimal qualifications for operators of various classes of treatment works." The Committee also has the duty of collecting and compiling data on present procedures in the licensing and certification of operators for reference to Member Associations.

W. A. Hasfurther, *Chairman*

M. F. Neuzil, *Vice-Chairman*

Benjamin Benas
J. E. Cooper
G. R. Frith
Ernest Hamilton
D. M. Pierce
T. J. Powers
T. C. Schaetzle
Sol Seid
H. S. Smith
S. L. Warrington

Awards Committee

L. S. Kraus, *Chairman*

Subcommittee on Eddy Award

J. C. Geyer, *Chairman*

E. R. Hermann
R. Manganelli

Subcommittee on Gascoigne Award

D. P. Backmeyer, *Chairman*

T. T. Hay
W. A. Sperry

Subcommittee on Emerson Award

E. Sherman Chase, *Chairman*

Earnest Boyce
W. D. Hatfield

Subcommittee on Industrial Wastes Award

W. R. Taylor, *Chairman*

W. W. Eckenfelder
R. H. Souther

Honorary Membership Committee

Authorized by the Board of Control on October 24, 1942, this Committee is comprised of the President and four latest, living Past Presidents with the senior Past President as chairman. The Committee reviews nominations for election to the grade of Honorary Member and makes recommendations to the Board on such nominations.

E. C. Jensen, *Chairman*

W. D. Hatfield
M. D. Hollis
R. E. Lawrence
K. S. Watson

Resolutions Committee

The Resolutions Committee was created by the Board of Control on October 9, 1958. Its function is to recommend to the Board of Control appropriate resolutions.

E. J. Beatty, *Chairman*

C. H. Billings
T. T. Hay

Legislative Analysis Committee

The Legislative Analysis Committee was created by the Board of Control on October 17, 1945, to study legislation pertinent to the interests of the Federation and to serve the Board in advisory capacity.

R. S. Shaw, *Chairman*

J. H. Allen
V. W. Bacon
C. M. Everts, Jr.
R. K. Horton
K. Krause
D. B. Lee
D. F. Smallhorst
C. R. Walbridge

Quarter Century Operators' Club Committee

The special Quarter Century Operators' Club Committee was created by the Board of Control on October 9, 1946. It is the function of this Committee to establish eligibility requirements, process membership applications, maintain the roster, and supervise the activities of the Quarter Century Operators' Club.

H. Van Der Vliet, *Chairman*

A. H. Niles
Andrew Palmer
H. W. Streeter

Constitution and Bylaws Committee

The Constitution and Bylaws Committee was created by the Board of Control on October 10, 1947, to review and develop recommendations for the amendment of the Constitution and Bylaws of the Federation as may be deemed advisable under changing conditions.

G. J. Schroepfer, *Chairman*

R. F. Weston, *Vice-Chairman*

E. Boyce
F. J. McKee
W. J. Orchard
M. L. Robins
W. H. Wisely

Safety Committee

This Committee was created in 1954 for the purpose of maintaining close liaison between the Federation and the National Safety Council in the fields common to both organizations.

J. J. Wirts, *Chairman*

G. L. Burt
U. T. Mann
W. W. Mathews
H. A. Schreiber
W. N. Torpey
L. W. Van Kleeck

Public Relations Committee

This Committee was created in 1957 to determine what activities could be undertaken in the field of stream pollution control and waste treatment, and to help the Federation to direct its activities accordingly.

G. A. Howell, *Chairman*

K. S. Watson, *Vice-Chairman*

C. H. Billings
A. C. Bryan
L. S. Dukes
C. C. Larson
D. B. Lee
H. Ludwig
J. E. Meers
H. Sandt
E. S. Tisdale
J. A. Zaffle

Nuclear Wastes Committee

This Committee was created in 1957 to study the responsibility of the Federation in this role and recommend activities in harmony with the Federation's objectives.

J. M. Smith, Jr., *Chairman*

R. E. Foster
E. F. Gloyna
W. N. Grune
W. J. Kaufman
J. A. Lieberman
B. A. Poole
C. P. Straub

JOINT COMMITTEES WITH OTHER ORGANIZATIONS

(Also see Sewage and Industrial Wastes Practice Committee)

Federation Representatives, ASEIB

This Committee was authorized by the Board of Control to represent the Federation on the American Sanitary Engineering Intersociety Board. The objectives of this Board include recognition of sanitary engineers through formal certification.

WPCF Representatives

E. C. Jensen
H. Ludwig
D. F. Metzler

Joint Committee on Chlorine Supply

On October 11, 1951, the Board of Control authorized participation in the Joint Committee on Chlorine Supply with the American Water Works Association and the Conference of State Sanitary Engineers. The objective of the Committee is to study problems of chlorine supply and distribution in the water and sewage fields, and to develop recommendations for their solution.

WPCF Representatives

H. A. Faber
W. E. Gerdel

Joint Committee on Water and Sewage Works Operators' Certification

WPCF Representatives

Julian Fleming, *Chairman*

W. M. Bingley
W. A. Hasfurther
Sol Seid

Joint Policy Committee

This Joint Committee was created in 1954 to provide a unified approach to problems or actions arising by reasons of emergencies or in the common interest. Representation on the Committee is held by the Federation, the American Water Works Association, and the Water and Sewage Works Manufacturers' Association.

WPCF Representatives

R. E. Fuhrman
W. D. Hatfield
M. D. Hollis
R. E. Lawrence
W. J. Orchard
K. S. Watson

ASTM Committee D-19

R. S. Ingols
W. A. Moore

Joint Committee for Uniformity of Methods for Water Examination

R. S. Ingols

SPECIAL CONVENTION COMMITTEES

Convention Management Committee

The function of this Committee is to supervise details of the management of the Annual Meetings of the Federation.

H. E. Schlenz, *Chairman*

C. G. R. Armstrong
E. J. Beatty
R. E. Fuhrman
J. G. Stewart

Meeting Place Committee

This Committee reviews invitations received for the Annual Meetings of the Federation and makes recommendations to the Board of Control in regard to the time and place of such meetings.

R. E. Lawrence, *Chairman*

R. E. Fuhrman
M. D. Hollis
G. W. Kelsey
C. V. Roberts
H. E. Schlenz
J. G. Stewart

MEMBERSHIP SUMMARY

(*As of December 31, 1960*)

Federation Members

Honorary Members	14
Associate Members	85
Member Associations (44)	
Active Members	8,249
Corporate Members	250

Net Membership of Member Associations

Member Association	Active	Honorary	Corporate	Total
Alabama	54	—	1	55
Alaska	15	—	—	15
Arizona	47	—	4	51
Arkansas	33	—	4	37
California	602	1	2	605
Canada	647	1	—	648
Central States	608	3	22	633
England-IPHE	21	—	—	21
England-ISP	114	—	—	114
Federal	91	1	—	92
Florida	434	—	1	435
Georgia	79	—	3	82
Germany	47	1	—	48
Indiana	254	—	28	282
Iowa	136	—	—	136
Kansas	135	—	1	136
Kentucky-Tennessee	190	—	6	196
Louisiana	16	—	—	16
Maryland-Delaware	86	—	6	92
Michigan	500	1	2	503
Mississippi	81	—	8	89
Missouri	68	—	5	73
Montana	35	—	3	38
Nebraska	66	—	—	66
New England	415	3	—	418
New Jersey	334	—	—	334
New York	633	2	33	668
New Zealand	40	—	—	40
North Carolina	175	—	—	175
North Dakota	19	—	—	19
Ohio	408	2*	34	442
Oklahoma	48	—	—	48
Pacific Northwest	358	—	9	367
Pennsylvania	500	1	28	529
Puerto Rico	80	—	—	80
Rocky Mountain	128	—	5	133
South Carolina	63	—	2	65
South Dakota	43	—	—	43
Sweden	126	—	—	126
Switzerland	17	—	—	17
Texas	234	—	4	238
Utah	49	—	3	52
Virginia	139	—	25	164
West Virginia	81	—	11	92
Totals	8,249	14	250	8,513

* New in 1960, not included in total.

MEMBER ASSOCIATIONS

Alabama Water and Sewage Association—Sewage Works Section (Affiliated 1948).

Area: Alabama.
President: Clifford C. Williams; *Vice-President:* Raymond C. Ross; *Director:* John M. Bolton; *Treasurer:* Charles D. Hart; *Secretary:* E. J. Finnell, Jr., University of Alabama, University, Ala.

Alaska Water Management Association (Affiliated 1960).

Area: Alaska.
President: LaMar Hubbs; *Vice-President* (Northern Region): Harold Gillam; *Vice-President* (South-Central Region): Henry H. Staley; *Vice-President* (Southeastern Region): Alfred Baker; *Director:* LaMar Hubbs; *Secretary-Treasurer:* Charles F. Walters, Arctic Health Research Center, P. O. Box 960, Anchorage, Alaska.

Arizona Sewage and Water Works Association—Sewage Works Section (Affiliated 1928).

Area: Arizona.
President: R. E. Polenske; *First Vice-President:* Stanford I. Roth; *Second Vice-President:* Milford E. Devine; *Director:* E. O. Dye; *Secretary-Treasurer:* A. D. Cox, Jr., 2612 N. 16th St., Phoenix, Ariz.

Arkansas Water and Sewage Conference—Sewage Works Section (Affiliated 1946).

Area: Arkansas.
Chairman: Bob L. Rimmer; *Director:* M. L. Wood; *Secretary-Treasurer:* C. W. Oxford, College of Engineering, University of Arkansas, Fayetteville, Ark.

California Sewage and Industrial Wastes Association (Affiliated 1928).

Area: California.
President: Dennis O'Leary; *First Vice-President:* Elmer Ross; *Second Vice-President:* Paul V. Hennessy; *Directors:* H. H. Hunt and Robert D. Bargman; *Secretary-Treasurer:* Robert L. White, Bureau of Engineering, City Hall, Burbank, Calif.

Canadian Institute on Sewage and Sanitation (Affiliated 1933).

Area: Canada.
President: Ross L. Clark; *Vice-President:* Fred M. Woods; *Director:* C. G. Russell Armstrong; *Secretary-Treasurer:* A. E. Berry, Administrative Office, 72 Grenville St., Toronto 8, Ont., Canada.

Central States Sewage and Industrial Wastes Association (Affiliated 1928).

Area: Illinois, Wisconsin, and Minnesota.
President: Walter A. Sperry; *First Vice-President:* Thomas T. Hay; *Second Vice-President:* John C. Sager; *Directors:* E. J. Beatty and Harvey G. Rogers; *Secretary-Treasurer:* Scott E. Linsley, 2400 Childs Rd., St. Paul 6, Minn.

(England) Institute of Sewage Purification (Affiliated 1932).

Area: Commonwealth and dependent territories.
President: M. A. Kershaw; *First Vice-President:* Martin Lovett; *Second Vice-President:* A. Holroyd; *Director:* W. F. A. Snook; *Treasurer:* L. B. Phillipps; *Secretary:* W. F. A. Snook, 10 Cromwell Pl., S. Kensington, London, S. W. 7, England.

(England) Institution of Public Health Engineers (Affiliated 1932).

Area: Commonwealth and dependent territories.
President: J. T. Calvert; *Vice-President:* N. J. Tatman; *Director:* James M. L. Bogle; *Treasurer:* A. Seiver; *Secretary:* Ernest V. Balsom, 179 Vauxhall Bridge Rd., London, S. W. 1, England.

Federal Sewage Research Association (Affiliated 1930).

Area: Federal employees wherever stationed.
President: Keith S. Krause; *Vice-President:* Ralph H. Holtje; *Director:* G. E. McCallum; *Secretary-Treasurer:* Martin F. Kunkel, Room 4232, HEW South Bldg., Washington 25, D. C.

Florida Pollution Control Association (Affiliated 1941).

Area: Florida.
President: M. E. Dawkins; *Vice-President:* Ellis K. Phelps; *Director:* David B. Smith; *Secretary-Treasurer:* Vincent D. Patton, State Board of Health, Box 210, Jacksonville 1, Fla.

Georgia Water and Sewage Association—Wastes Section (Affiliated 1936).

Area: Georgia.
Chairman: Lewis Simonton; *Vice-Chairman:* McDewain Sandlin; *Director:* M. B. Nixon; *Secretary-Treasurer:* Robert S. Ingols, Prof., Applied Biology, Georgia Institute of Technology, Atlanta, Ga.

German Sewage and Industrial Wastes Association (Affiliated 1950).
(Abwassertechnische Vereinigung)

Area: Germany.
President: Guenther Mueller-Neuhaus; *First Vice-President:* Wilhelm Husmann; *Second Vice-President:* Hans Koester; *Third Vice-President:* Franz Schmitz-Lenders; *Director:* Wilhelm Husmann; *Secretary-Treasurer:* Karl Reger, 8 Bertha von Suttner Place, Bonn, Germany.

Indiana Water Pollution Control Association (Affiliated 1958).

Area: Indiana.
President: George K. Erganian; *First Vice-President:* Dwight O. Bender; *Second Vice-President:* Frank D. Wraight; *Director:* W. W. Mathews; *Secretary-Treasurer:* Victor G. Wagner, State Department of Health, 1330 W. Michigan St., Indianapolis 7, Ind.

Iowa Water Pollution Control Association (Affiliated 1928).

Area: Iowa.
President: Marcus P. Powell; *Vice-President:* D. P. Morrow; *Director:* H. S. Smith; *Treasurer:* Harry E. Boren; *Secretary:* L. F. Skorczeski, 207 S. 15th Ave., Marshalltown, Iowa.

Kansas Water Pollution Control Association (Affiliated 1935).

Area: Kansas.
Chairman: Harry Pfautz; *First Vice-Chairman:* John Glidewell; *Second Vice-Chairman:* N. J. Burris; *Director:* Carl Hodgkinson; *Secretary-Treasurer:* Howard F. Saiger, 1900 E. 9th St., Wichita, Kans.

Kentucky-Tennessee Water Pollution Control Association (Affiliated 1946).

Area: Kentucky and Tennessee.
Chairman: C. M. Fair; *Vice-Chairman:* Jack A. Henshaw; *Director:* M. A. Churchill; *Secretary-Treasurer:* S. Leary Jones, 602 Cordell Hull Bldg., Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage—Sewage Works Section (Affiliated 1949).

Area: Louisiana.
Chairman: A. J. Szabo; *Director:* H. J. Scioneaux; *Secretary-Treasurer:* George H. West, P. O. Box 895, Water Department, Lake Charles, La.

Maryland-Delaware Water and Sewage Association—Sewage Works Section (Affiliated 1928).

Area: Maryland, Delaware, and District of Columbia.
President: C. Gordon Reinsburg; *First Vice-President:* A. Joel Kaplovsky; *Second Vice-President:* Roy L. Orndorff; *Director:* William A. Hasfurther; *Secretary-Treasurer:* W. M. Bingley, State Department of Health, 301 W. Preston St., Baltimore 1, Md.

Michigan Sewage and Industrial Wastes Association (Affiliated 1930).

Area: Michigan.
President: Fred Galarno; *First Vice-President:* Robert F. Killeen; *Second Vice-President:* Ralph A. Garno; *Directors:* George E. Hubbell and G. F. Wyllie; *Secretary-Treasurer:* Donald M. Pierce, Michigan Department of Health, Room 331, Administration Bldg., Lansing 4, Mich.

Mississippi Sewage and Industrial Wastes Association (Affiliated 1957).

Area: Mississippi.
President: James E. Jagger; *Vice-President:* Tom W. Stallworth; *Director:* G. M. Lester; *Secretary-Treasurer:* Neil G. McMahon, Mississippi State Board of Health, Jackson, Miss.

Missouri Water Pollution Control Association (Affiliated 1929).

Area: Missouri.
Chairman: Werner F. Heidtke; *Vice-Chairman:* Allen Mayfield; *Director:* William G. Riddle; *Secretary-Treasurer:* Jack K. Smith, Water Pollution Control Board, 112 W. High, P. O. Box 154, Jefferson City, Mo.

Montana Sewage and Industrial Wastes Association (Affiliated 1944).

Area: Montana.
Chairman: William J. Wenzel; *Vice-Chairman:* Ben Chestnut; *Director:* Tom Schultz; *Secretary-Treasurer:* A. W. Clarkson, Division of Environmental Sanitation, State Board of Health, Helena, Mont.

Nebraska Sewage and Industrial Wastes Association (Affiliated 1952).

Area: Nebraska.
President: Walter Arfmann; *Vice-President:* Carl Chin; *Director:* T. A. Filipi; *Secretary-Treasurer:* E. Bruce Meier, Kirkham, Michael & Assoc., 508 S. 19th St., Omaha 2, Nebr.

New England Water Pollution Control Association (Affiliated 1929).

Area: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island.
President: Joseph B. Hanlon; *First Vice-President:* Howard F. Carpenter; *Second Vice-President:* Earl R. Howard; *Director:* Charles G. Hammann; *Secretary-Treasurer:* Richard F. Greeley, Massachusetts Department of Health, 511 State House, Boston 33, Mass.

New Jersey Water Pollution Control Association (Affiliated 1942).

Area: New Jersey.
President: Michael Kachorsky; *First Vice-President:* John Frazee; *Director:* John J. Horgan; *Treasurer:* Henry Van Der Vliet; *Secretary:* Anthony T. Leahey, P. O. Box 32, West Trenton, N. J.

New York Water Pollution Control Association (Affiliated 1930).

Area: New York.
President: Guy E. Griffin; *Vice-President:* John J. Baffa; *Directors:* G. A. Fleet and R. C. Sweeney; *Treasurer:* D. B. Stevens; *Secretary:* Ralph C. Sweeney, State Department of Health, 55 Church St., White Plains, N. Y.

New Zealand Sewage and Industrial Wastes Association (Affiliated 1957).

Area: New Zealand.
Chairman: M. B. Rands; *Vice-Chairman:* S. Oldfield; *Director:* P. R. Parr; *Secretary:* K. R. Davis, Auckland Metropolitan Drainage Board, P. O. Box 208, Auckland C. 1, New Zealand.

North Carolina Water Pollution Control Association (Affiliated 1929).

Area: North Carolina.
Chairman: L. P. Bloxam; *Vice-Chairman:* J. H. Henderlite; *Director:* Lee S. Dukes, Jr.; *Secretary-Treasurer:* T. Z. Osborne, Room 309 Municipal Bldg., Greensboro, N. C.

North Dakota Water Pollution Control Association (Affiliated 1936).

Area: North Dakota.
President: Richard Fuller; *Vice-President:* Glenn Berg; *Director:* Norman Peterson; *Secretary-Treasurer:* W. Van Heuvelen, State Department of Health, Bismarck, N. Dak.

Ohio Water Pollution Control Conference (Affiliated 1932).

Area: Ohio.
Chairman: A. D. Caster; *First Vice-Chairman:* R. N. Simonsen; *Second Vice-Chairman:* Max Phillips; *Director:* Earl F. Wittmer; *Secretary-Treasurer:* E. B. Ransom, Ohio Department of Health, 101 N. High St., Columbus 15, Ohio.

Oklahoma Water, Sewage and Industrial Wastes Conference—Sewage Works Section (Affiliated 1929).

Area: Oklahoma.
President: W. J. Gossom; *Vice-President:* Marion Buercklin; *Director:* L. L. Settle; *Secretary-Treasurer:* H. M. Crane, State Department of Health, 3400 N. Eastern, Oklahoma City 5, Okla.

Pacific Northwest Pollution Control Association (Affiliated 1933).

Area: Washington, Oregon, and Idaho.
President: Raymond S. Fish; *Vice-President:* C. S. Zickefoose; *Director:* R. Trumbull Smith; *Secretary-Treasurer:* Gilbert H. Dunstan, P. O. Box 176, Pullman, Wash.

Pennsylvania Water Pollution Control Association (Affiliated 1928).

Area: Pennsylvania.
President: A. A. Estrada; *First Vice-President:* John Yenchko; *Second Vice-President:* Thomas Iezzi; *Directors:* H. W. McElhaney and S. I. Zack; *Secretary-Treasurer:* J. R. Harvey, Regional Sanitary Engineer, Pennsylvania Department of Health, 996 S. Main St., Meadville, Pa.

Puerto Rico Water and Sewage Works Association (Affiliated 1947).

Area: Puerto Rico.
President: Israel Rivera-Marini; *Vice-President:* Pedro Hernandez-Vega; *Director:* G. Flaque-Garces; *Secretary-Treasurer:* Robert J. Auld, Espana 2015, Ocean Park, Santurce, Puerto Rico.

Rocky Mountain Sewage and Industrial Wastes Association (Affiliated 1947).

Area: Wyoming, Colorado, and New Mexico.
President: Arthur B. Chafetz; *Vice-President:* Verne E. Plath; *Director:* Anthony Rossi; *Secretary-Treasurer:* John W. Hernandez, 408 Galisteo St., Santa Fe, N. Mex.

South Carolina Water and Sewage Works Association—Sewage Works Section (Affiliated 1949).

Area: South Carolina.
Chairman: J. D. Lesslie; *Vice-Chairman:* H. H. Connelly; *Director:* J. D. Lesslie; *Treasurer:* Thomas P. Anderson; *Secretary:* Robert N. Bowen, 417 Wade Hampton Bldg., Columbia, S. C.

South Dakota Water Pollution Control Association (Affiliated 1936).

Area: South Dakota.
President: Charles R. Price; *Vice-President:* N. A. Erickson; *Director:* Don C. Kalda; *Secretary-Treasurer:* Don C. Kalda, Division of Sanitary Engineering, State Board of Health, Pierre, S. Dak.

Swedish Association for Water Hygiene (Affiliated 1952).
(Föreningen för Vattenhygien)

Area: Sweden.
President: V. Jansa; *Vice-President:* Erik Vasseur; *Director:* V. Jansa; *Secretary:* Erik Jonsson, Box 5038, Humlegardsgatan 29, Stockholm 5, Sweden.

Swiss Association of Water and Sewage Professionals (Affiliated 1947).
(Verband Schweizerischer Abwasserfachleute)

Area: Switzerland.
President: André Kropf; *Director:* André Kropf; *Treasurer:* Eduard Holinger; *Secretary:* Pierre Wildi, Hegemmatt 28, Zurich 2/38, Switzerland.

Texas Water and Sewage Works Association—Sewage and Industrial Wastes Section (Affiliated 1928).

Area: Texas.
Chairman: Cecil H. Williams; *First Vice-Chairman:* John P. Wold; *Second Vice-Chairman:* William N. Wells; *Director:* J. L. Robinson; *Secretary:* G. R. Herzik, Jr., Sanitary Engineering Division, State Department of Health, Austin, Tex.; *Assistant Secretary and Treasurer:* Mrs. E. H. Goodwin.

Utah Water Pollution Control Association (Affiliated 1957).

Area: Utah.
President: Harold A. Linke, Jr.; *Vice-President:* Howard B. Kelly; *Director:* Howard M. Hurst; *Secretary-Treasurer:* William W. Anderton, Supervisor, Sewage Treatment Plant, 2500 S. State St., Salt Lake City 15, Utah.

Virginia Industrial Wastes and Sewage Works Association (Affiliated 1947).

Area: Virginia.
President: Harry L. Hale; *Vice-President:* Chalkley DuVal; *Director:* E. H. Ruehl; *Secretary-Treasurer:* Orval J. Hand, Hercules Powder Co., Hopewell, Va.

West Virginia Water Pollution Control Association (Affiliated 1947).

Area: West Virginia.
President: Rex C. Pierson; *First Vice-President:* Richard L. Williams; *Second Vice-President:* Bern Wright; *Director:* Paul T. Arbuckle; *Secretary-Treasurer:* Glen O. Fortney, State Department of Health, Charleston 5, W. Va.

HONORARY MEMBERS *

Berry, Albert E. (1954), Gen. Mgr., Ont. Water Resources Comm., 235 Gainsboro Rd., Toronto 8, Ont., Can. (Can.)

Boyce, Earnest (1959), Prof., San. Engr., Chmn., Dept. of Civ. Engr., Univ. of Michigan, 304 W. Engineering Bldg., Ann Arbor, Mich. (Mich.)

Chase, E. Sherman (1958), Cons. Engr., Partner, Metcalf & Eddy, 1300 Statler Bldg., Boston 16, Mass. (N. Eng.)

Cohn, Morris M. (1957), Editor, Wastes Engineering Magazine, 466 Lexington Ave., New York 17, N. Y. (N.Y.)

DeBerard, Wilford Willis (1950), Deputy Commr. of Water and Chief Water Engr., Bur. of Engr., Dept. of Pub. Works, 402 City Hall, Chicago 2, Ill. (Cen. St.)

Fair, Gordon Maskew (1955), Head, Dept. of San. Engr., Harvard Univ., 935 Memorial Dr., Cambridge 38, Mass. (N. Eng.)

Friel, Francis S. (1959), Pres., Albright & Friel, Inc., Suite 1500, 3 Penn Center Plaza, Philadelphia 2, Pa. (Pa.)

Gilcreas, F. Wellington (1948), Prof. of San. Science, Univ. of Florida, Gainesville, Fla. (N. Eng.)

Hyde, Charles Gilman (1943), Cons. Engr., 2599 Buena Vista Way, Berkeley 8, Calif. (Calif.)

Imhoff, Karl (1953), Cons. Engr., Robert Schmidt Str. 8, Essen, Germany (Germany)

Niles, Arthur H. (1960), Consultant, 433 N.E. 33rd St., Boca Raton, Fla. (Ohio)

Orchard, William J. (1946), Wallace & Tiernan Inc., 25 Main St., Belleville, N. J. (N.Y.)

Schroepfer, George J. (1958), Prof., San. Engr., Univ. of Minnesota, 280 Experimental Engr. Bldg., Minneapolis 14, Minn. (Cen. St.)

Streeter, Harold W. (1953), San. Engr., USPHS, Box 192, RR 1, Old Indian Hill Rd., Cincinnati 27, Ohio (Fed.)

Wisely, W. H. (1956), Exec. Sec.-Ed., American Soc. of Civ. Engr., 33 W. 39th St., New York 18, N. Y. (Cen. St.)

ASSOCIATE MEMBERS

Individuals named represent their companies.

Airkem, Inc., 241 E. 44th St., New York 17, Nicholas K. Post.

Alpha Ltd., Nidau, Switzerland, H. Thurnheer, Vice-Dir.

American Cast Iron Pipe Co., P. O. Box 2603, Birmingham, Ala., J. W. MacKay, Vice-Pres., Sales.

American City Magazine, 470 Park Ave., South, New York 16, Edgar J. Buttenheim, Chmn. of the Bd.

American Concrete Pipe Assn., 228 N. LaSalle St., Suite 1033, Chicago 1, Ill., Howard F. Peckworth, Mng. Dir.

American Pipe & Construction Co., P. O. Box 3428, Terminal Annex, Los Angeles 54, Calif., C. D. Herlihy, Gen. Sales Mgr.

American Well Works, 100 N. Broadway, Aurora, Ill., S. A. Karlin, Pres.

Armco Drainage & Metal Products, Inc., Middletown, Ohio, J. M. Robertson, Sales Mgr., Drainage & Allied Sales Dept.

B-I-F Industries, Inc., 345 Harris Ave., Providence 1, R. I., G. W. Kelsey, Sr., Vice-Pres.

Bird Machine Co., Centrifugal & Filtration Equip., South Walpole, Mass., E. G. Piper, Sales Mgr.

* Year of election to Honorary Membership and Member Association affiliation shown in parentheses.

Carter, Ralph B., Co., Waste Treatment Equip. Div., 192 Atlantic St., Hackensack, N. J., J. L. Ledeen, Gen. Mgr.

Centriline Corp., 140 Cedar St., New York 6, W. E. Borbonus, Pres.

Chain Belt Co., P. O. Box 2022, Milwaukee 4, Wis., William Sivyer, Div. Mgr.

Chapman Valve Manufacturing Co., 203 Hampshire St., Indian Orchard, Mass., Roger M. Westcott, Chief Sales Engr.

Chicago Pump Co., Hydrodynamics Div., Food Machinery & Chemical Corp., 622 W. Diversey Pkwy., Chicago 14, Ill., Milton Spiegel, Gen. Mgr.

Combustion Engineering, Inc., Raymond Div., 427 W. Randolph St., Chicago 6, Ill., C. A. Leet.

Corrosion Control Co., Inc., 33 W. 42nd St., New York 36, Joseph C. Roach, Vice-Pres.

Davco Corp., 1828 Metcalf Ave., Thomasville, Ga., Jack Hedrick, Sales Mgr.

DeZurik Corp., Sartell, Minn., David DeZurik, Jr., Sales Dir.

Dorr-Oliver Inc., Havemeyer La., Stamford, Conn., W. A. Darby, Mgr., San. Sales Area.

Dow Industrial Service, Div. Dow Chemical Co., 20575 Center Ridge Rd., Cleveland 16, Ohio, W. B. Brown.

Elmco Corp., 634 S. 4th West St., Salt Lake City 10, Utah, Paul O. Richter, Vice-Pres. & Mgr., Filtration Div.

Engineering News-Record Magazine, 330 W. 42nd St., New York 36, R. F. Boger, Publisher.

Evanite Plastic Co., Div. of Evans Pipe Co., Uhrichsville, Ohio, Walter S. Prendergast, Gen. Mgr.

Everson Manufacturing Corp., 214 W. Huron St., Chicago 10, Ill., R. B. Everson, Pres.

Fairbanks, Morse & Co., Pump & Hydraulic Div., 3601 Kansas Ave., Kansas City 5, Kans., W. F. Wahlenmaier, Dir., Marketing.

Fischer & Porter Co., Hatboro, Pa., Douglas E. Dismukes, Gen. Mgr., Water & Waste Div.

Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa., George E. McCain, Mgr., Furniture.

Flexible Inc., 3786 Durango Ave., Los Angeles 34, Calif., Peter L. Ciaccio, Mgr.

Foxboro Co., Water & Waste Div., Foxboro, Mass., Russell H. Babcock, Mgr.

General Electric Co., 1 River Rd., Schenectady 5, N. Y., E. O. Potthoff.

Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio, James C. Gorman, Sales Mgr.

Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis 6, Mo., William P. Gruendler, Pres.

Hach Co., Box 597, Ames, Iowa, Clifford Hach, Pres.

Hardinge Co., Inc., York, Pa., C. S. Horning.

Homestead Valve Manufacturing Co., Box 348, Coraopolis, Pa., F. E. Schuchman.

Industrial Materials Co., Somerset St. & Trenton Ave., Philadelphia 34, Pa., John M. Riordan, Pres.

Inertol Co., Inc., 480 Frelinghuysen Ave., Newark 12, N. J., G. W. Rupp.

Infilco Inc., 901 S. Campbell Ave., P. O. Box 5033, Tucson, Ariz., G. E. Hauer.

Jeffrey Manufacturing Co., Columbus 16, Ohio, S. L. Tolman.

Johns-Manville Corp., 22 E. 40th St., New York 16, R. F. Orth, Vice-Pres.

Keasbey & Mattison Co., Asbestos Cement Pipe Dept., Ambler, Pa., Alan F. Nagle.

Komline-Sanderson Engineering Corp., Box 257, Peapack, N. J., T. K. Komline, Pres.

Koppers Co., Inc., Tar Products Div., Pittsburgh 19, Pa., J. N. Grossett.

Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.

Link-Belt Co., Colmar Plant, Colmar, Pa., J. J. Gilbert, Engr. in Charge, San. Engr. Equip.

Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J., Paul E. Maloney, Div. Sales Mgr.

Marlow Pumps, Div. of Bell & Gossett Co., Box 200, Midland Park, N. J., O. L. Eriksen, Mgr., Ind. Sales.

Minneapolis-Honeywell Regulator Co., Ind. Products Group, Wayne & Windrim Ave., Philadelphia 44, Pa., F. L. Mascitti, Market Mgr., Mun. Serv.

Morse Boulger, Inc., Sewage & Waste Div., 80 Fifth Ave., New York 11.

Mueller Co., 512 W. Cerro Gordo St., Decatur, Ill., Dan R. Gannon.

Municipal Service Co., 4625 Roanoke Pkwy., Kansas City, Mo., H. R. Oglesby, Jr., Vice-Pres. & Gen. Mgr.

National Water Main Cleaning Co., 50 Church St., New York 5, J. A. Frank, Pres.

Nichols Engineering & Research Corp., 80 Pine St., New York 5, Mark B. Owen.

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill., L. E. Langdon, Vice-Pres. & Sales Mgr.

Penn Instruments Div., Burgess-Manning Co., 4110 Haverford Ave., Philadelphia 4, Pa., Wynn Williams.

Perry-Austen Manufacturing Co., 250 Parkinson Ave., Staten Island 5, N. Y., Eric P. Hartmann, Sales Mgr.

Pittsburgh-Des Moines Steel Co., Pittsburgh 25, Pa., T. W. Fauntleroy, Vice-Pres. & Sales Mgr.

Preload Co., Inc., 355 Lexington Ave., New York 17, E. H. Thwaits, Vice-Pres.

Price Brothers Co., 1932 E. Monument Ave., P. O. Box 825, Dayton 1, Ohio, Harry S. Price, Jr., Exec. Vice-Pres.

Public Works Magazine, 200 S. Broad St., Ridgewood, N. J., W. A. Hardenbergh, Pres.

Robinson Clay Product Co., P. O. Box 1070, Akron 9, Ohio, P. V. Robinson, Jr., Sales Mgr.

Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 8, Pa., Everett M. Jones.

Roots-Connersville Blower, Div. of Dresser Industries, Inc., 900 W. Mount St., Connersville, Ind., G. H. Crocker, Gen. Sales Mgr.

Simplex Valve & Meter Co., 7–17 E. Orange St., Lancaster, Pa., F. E. Gerlitz, Jr., Sales Mgr.

Smith, A. O., Corp., Atomic & Process Equip. Div., P. O. Box 584, Milwaukee 1, Wis., H. K. Brill, Gen. Sales Mgr.

Smith, A. P., Manufacturing Co., 545 Arlington Ave., East Orange, N. J.

Smith-Blair, Inc., P. O. Box 666, South San Francisco, Calif.

Smith & Loveless, Div.-Union Tank Car Co., Lenexa, Kans., B. Alden Smith.

Stuart Corp., 516 N. Charles St., Baltimore, Md., Fred E. Stuart, Sr., Pres.

Sutorbilt Corp., 2966 E. Victoria St., Compton, Calif., Sune V. Malmgren, Sr., Field Engr., Sewage & Ind. Wastes.

Tex-Vit Manufacturing Co., P. O. Box 117, Mineral Wells, Tex., S. V. Prator, Mgr.

Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

Walker Process Equipment Inc., Aurora, Ill., J. D. Walker, Pres.

Wallace & Tiernan Inc., 25 Main St., Belleville 9, N. J., T. T. Quigley, Vice-Pres., Equip. Div.

Wastes Engineering Magazine, 466 Lexington Ave., New York 17, Alfred J. Houghton, Publisher.

Water & Sewage Works Magazine, 185 N. Wabash Ave., Chicago 1, Ill., E. S. Gillette.

Waukesha Motor Co., Waukesha, Wis., F. Gunther.

WEMCO Div. of Western Machinery Co., 650 Fifth St., San Francisco 7, Calif., Elwood E. Cone.

Westinghouse Electric Corp., 3 Gateway Center, Pittsburgh 30, Pa., J. D. Witherspoon.

W-K-M Div. of ACF Industries, Inc., P. O. 2117, Houston 1, Tex., R. D. Butler.

Wood, R. D., Co., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa., W. Davies, Sales Mgr.

Worthington Corp., Harrison, N. J., D. L. Gallagher, Pub. Works Cons.

Yeomans Brothers Co., 1999 N. Ruby St., Melrose Park, Ill., D. W. Burgoon, Pres.

Zimmermann Process Div., Sterling Drug, Inc., Salvo Chemical Corp., Rothschild, Wis., Neal Seegert, Sales Mgr.

SUPPLEMENTARY MEMBERSHIP DIRECTORY *

The last full membership listing, published in the March 1960 issue of THIS JOURNAL, gave the membership roster of Member Associations as of December 31, 1959. This supplementary listing, therefore, includes only the names and addresses of those who have been added to that previous listing as new or reinstated members during 1960 and therefore were not included in the main biennial listing.

Ackworth, J. C., Head Opr., Trt. Plt., 1010 Willow Dr., RR 10, London, Ont., Canada

Acton, Richard L., Sales Engr., Moline Malleable Iron Co., 801 E. Excelsior Ave., Hopkins, Minn.

Adcock, Fred, Chief Opr., City of Atwater, Box 485, Atwater, Calif.

Adrian, Donald Dean, Asst. San. Engr., Dept. of Pub. Health, Bur. of San. Engr., 322 Panoramic Way, Berkeley 4, Calif.

Agardy, Franklin J., Assoc., Univ. of California, Civ. Engr. Dept., 115-D 9th St., Albany 10, Calif.

Aikins-Afful, Eb, Stud., Univ. of Wisconsin, Hydr. & San. Lab., Madison, Wis.

Aireactor of Rochester, Inc., Att.: Samuel M. Spinelli, 556 Bayview Rd., Rochester 9, N. Y.

Akers, Robert H., Sales Engr., Armco Drainage & Metal Products, Inc., 1820 Northwest Bldg., Columbus 12, Ohio

Akers, Ward L., San. Engr., Illinois Dept. of Pub. Health, 925 Cleveland Ave., Springfield, Ill.

Albone, T., Sr. Engr., Trans-Canada Pipe Lines Ltd., 150 Eglinton Ave., E., Toronto 12, Ont., Canada

Alder, L. L., see Borg-Warner Corp.

Allen, Bernard W., Opr., Sewage Trt. Plt., Box 56, Lebanon, Ohio

Allen, John H., Mgr., Town of Fayetteville, Box 298, Fayetteville, W. Va.

Allen, Lyman H., Jr., Chief Engr., Internatl. Flavors & Fragrances, Inc., 800 Rose La., Union Beach, N. J.

Alley, Lawrence A., Partner, Alley & Williams, Box 1336, Burlington, N. C.

Alvarez, Alfonso, San. Engr., Manuel Barrios 4627, Santiago, Chile, S. A. (Cen. St.)

Anaconda Aluminum Co., Att.: G. O. Gray, Box 1607, Terre Haute, Ind.

Anderson, Steven J., Grad. Stud., Syracuse Univ., 44 Cooper Rd., Dover, Del. (N. Y.)

Andres, Barry D., Dir., Lauman Lab., 100 Lauman La., Bethpage, N. Y.

Andrews, Johnnie F., Assoc. Prof., 1051 C. Monroe, Albany 6, Calif. (Ark.)

Andrus, Stephen R., Salesman, Johns-Manville Sales Corp., 460 Park Ave., San Jose, Calif.

Andryslak, R. S., see South Bend, City of

Angelo, Henry G., Gen. Foreman, 53 Tyler St., Bloomfield, Conn.

Annicelli, John P., San. Engr., Westchester Co., 8 Windmill La., New City, N. Y.

Antrim, Howard C., City Engr., City of Kansas City, 1313 Quindaro Blvd., Kansas City 4, Kans.

Apodaca, Emmanuel J., 801 Baca St., Santa Fe, N. Mex.

Arbogast, E. P., Town Engr., Town of Clarkstown, 62 Germonds Rd. W., New City, N. Y.

Arbuckle, Ed., Supt., Sewage Trt. Plt., City Hall, Jefferson, Iowa

Armco Drainage & Metal Products, Inc., Att.: C. B. Beerup, 3202 W. Sample St., South Bend, Ind.

Arthur, Robert M., Asst. Prof., Rose Polytechnic Inst., Terre Haute, Ind.

Atwood, J. D., Proc. Engr., Celanese Chemical Co., Gallipolis Ferry, W. Va.

Atwood, Raymond H., Sales Engr., 17 Fairlawn La., Lexington 73, Mass.

Ault, James C., Dir., San. Div., Knox County Health Dept., 209 E. Vanderbilt Dr., Oak Ridge, Tenn.

Axford, W. M., W. M. Axford & Assoc., 401 Ash Rd., Oakville, Ont., Canada

Baars, Kenneth L., Opr., Sewage Plt., 1502 Ruddiman Ave., North Muskegon, Mich.

Bailey, Harold, Opr., City of Rockford, 8 E. Bridge, Rockford, Mich.

Bailey, Harry H., Engr., Pomeroy & Assoc., 13864 Sayre St., San Fernando, Calif.

Baker, Alfred, Div. of Pub. Health, Box 1498, Ketchikan, Alaska

Bale, Harvey W., Asst. Engr., Albright & Friel, Inc., 18 S. 50th St., Philadelphia, Pa.

Ball, Harry D., Sales Engr., Seaforth Concrete Sewer Tile Co., Ltd., Clinton, Ont., Canada

Ballard, W. T., Engr., LaGloria Oil & Gas Co., Box 840, Tyler, Tex.

Bangert, Fred, Chief Opr., Sewage Plt., Billings, Mont.

Barlow, G., Mgr., Willow Holme Sewage Works, Carlisle, Cumberland, England (ISP)

Barlow, Jesse H., Rt. 1, Box 105, Richland, Mo.

Barnes, J. F., Chief Chem., Alliance Freezing Co., 208 Pomona St., Invercargill, New Zealand

Barnhart, E. L., Cons. Engr., 107–08 104 St., Ozone Park 17, N. Y.

Bartlett, Isaiah D., Chief Chem., City of Raleigh, Raleigh, N. C.

Bartolacci, Carl, Gen. Mgr., Pomerado Co. Water Dist., Poway, Calif.

Bascaron, Jose N., Civ. Engr., P. R. Water & Sewer Auth., Box 7066, Bo. Obrero Sta., Santurce, Puerto Rico

Baskerville, W. H., Pres., Patterson Assoc., Inc., Box 278, Gulf Breeze, Fla.

Batesville, City of, City Hall, Batesville, Ind.

Batson, W. Kelly, Owner, W. K. Batson Co., Box 3673, Charlotte 3, N. C.

Batson, W. T., Special Sales Rep., Faulkner Concrete Pipe Co., 400 W. Mayes, Jackson, Miss.

Baumgardner, Robert E., Engr., RD 2, Box 64, Ebensburg, Pa.

Baumgartner, John C., Tech. Supt., Tenn. River Pulp & Paper Co., Box 33, Counce, Tenn.

Bayon, Edward J., Cons., 45 Pleasant St., Holyoke, Mass.

Bayshore Sewerage Co., 1709 Union Ave., Hazlet, N. J.

Beach, Clarence O., Chief Opr., City of Battle Creek, 55 Maple Grove Ave., Battle Creek, Mich.

Beach, Wallace E., Field Rep., Canada Valve & Hydrant Co., Ltd., 150 Glenwood Dr., Brantford, Ont., Canada

Beattie, A. C., Engr., Ontario Water Resources Comm., 99 Dowling Ave., Apt. 107, Toronto, Ont., Canada

* Member Association affiliation shown in parentheses in all cases where the affiliation is not immediately evident from the member's address. See page 309 for complete listings of area served by each Member Association.

Beattie, Guy, Solvay Sales Corp., 40 Rector St., New York, N. Y. (N. J.)

Beck, Raymond A., Crestvale Trailer Pk., Box 42, Columbia, Mo.

Beeman, Earl R., Supt., Sewage Trt., City Bldg., Athens, Ohio

Beerup, C. D., see Armco Drainage & Metal Products, Inc.

Bell, Albert G., see Mt. Vernon Sewer Dist.

Bell, James W., National Canners Assn., 1133 20th St., N.W., Washington 6, D. C.

Bellet, John J., Supt., Water & Sewer Dept., City of Brighton, 420 S. 3rd St., Brighton, Mich.

Bellevue Sewer Dist., Att.: Arthur E. Zachau, Foreman, Box 598, Bellevue, Wash.

Belton Yarn Mill, Att.: Lewis H. Keeney, Engr., Belton, S. C. (Ga.)

Benjamin, Edward, Box 783, Grand Island, Nebr.

Bennett, Kenneth Howard, Universal Button Co., 824 Mason Headley Rd., Lexington, Ky.

Benton, E. A., Asst. Supt., City of Myrtle Beach, Myrtle Beach, S. C.

Berckmand, Louis A., Mfr. Rep., Ensign Products Co., Box 456, Smyrna, Ga.

Berkebile, Dale, Chmn., Bd. of Works, 911 Madison St., Rochester, Ind.

Berne, Gustave, Owner, Manatee Utility, Box 4140, Sarasota, Fla.

Berry, R. E., Cons. Engr., 103 Hearth Cresc., Kitchener, Ont., Canada

Bethalto Water Dept., Opr., 203 Oak St., Bethalto, Ill.

Bethke, Ben, Box 1781, Great Falls, Mont.

Betts, Clifford A., Jr., Assoc., Betts Engr. Co., Inc., 514 Lookout St., Chattanooga 3, Tenn.

Bickel, Robert L., 57 S. Anderson St., Aurora, Ill.

Birkel, Louis R., Wastes Control Engr., Republic Steel Corp., Res. Center, 6801 Brecksville Rd., Independence, Ohio

Birko Chemical Co., Att.: Ward Harris Smith, Pres., Box 1315, Denver, Colo. (Utah)

Bisher, Earle P., Chem. Engr., J. E. Sirrine Co., Box 960, Greenville, S. C.

Bishop, C. M., De Leuw Cather and Co. of Canada Ltd., 1491 Yonge St., Torono 7, Ont., Canada

Bixby, W. F., Mgr., Proc. Engr., B. F. Goodrich Chem. Co., 3135 Euclid Ave., Cleveland 15, Ohio

Bjorkman, Folke, Cons. Engr., Vattenbyggnadsbyran, Byggveien, Blokk 6, opg. A, Manglerud, Oslo, Norway (Sweden)

Blackwell, Churchill G., Blackwell Equipment & Supply Co., 1540 S. Albion St., Denver 22, Colo.

Blair, Mark V., Engr., Tests & Water Supply, Test Lab., Texas & Pacific Railway Co., 808 Fidelity Union Tower, 1507 Pacific Ave., Dallas 1, Tex.

Blair T. Bower, Meramec Basin Res. Proj., Givens Hall, Washington Univ., St. Louis 30, Mo.

Blampied, Paul G., Mfr., Johns-Manville Sales Corp., 100 Newbury St., Boston 16, Mass.

Blow, C. C., Sec., Auckland Metro. Drainage Bd., Box 208, Auckland, New Zealand

Board of Public Utilities, Att.: Reuben Cates, Plt. Engr., Box 450, Paris, Tenn.

Boardman, B. Richard, Cons. Engr., R. K. Kilborn & Assoc., 2267 5th Line W., Erindale, Ont., Canada

Boatwright, S. Joseph, Water Supt., City of Marion, Box 618, Marion, S. C.

Bodle, Benj. R., Jr., Plt. Opr., Clearfield Mun. Auth., 814 Turnpike Ave., Clearfield, Pa.

Boege, R. A., Gen. Mgr., Chief Engr., Union San. Dist., Box 508, Fremont, Calif.

Bogue, Stuart H., Design Engr., Pate & Hirn Inc., 532 Michigan Bldg., Detroit 26, Mich.

Bohlmann, R., Albert-Niemann-Str. 6, Hannover, Germany

Bologna, Alfred, Supt., Sewage Trt. Plt., Hopewell Twp. Mun. Bldg., Clark Blvd., Aliquippa, Pa.

Boone, C. C., Opr., Sewage Trt. Plt., City Hall, Chehalis, Wash.

Boren, M. M., Salesman, Pomona Terra-Cotta, Greensboro, N. C.

Borg-Warner Corp., Marbon Chemical Div., Att.: L. L. Alder, Asst. Chief Engr., Box 68, Washington, W. Va.

Borowski, Kenneth, Shift Opr., Sewage Plt., 317 W. Oak St., Ironwood, Mich.

Bosley, James P., Engr.-in-Training, Ohio Dept. of Health, 559 Solon Rd., Chagrin Falls, Ohio

Bourbonnais, Eugene E., Jr., Civ. Engr. Assoc., Engr. Div., 3051 Torrance Blvd., Torrance, Calif.

Bowen, W. C., Engr., Chem., R. B. Simms Filtration Plt., Rt. 2, Chesnee, S. C.

Boyce, Gifford R., Hillcrest Dr., Danville, N. J. (Md.-Del.)

Boyce, Robert P., Opr., Clearfield Sewage Auth., 210 Turnpike Ave., Clearfield, Pa.

Bozich, Thomas A., USAF, 278 Wherry Housing, Layton, Utah (Ohio)

Brackett, W. H., Mfr., Box 101, Wellesley Hills 81, Mass.

Bradley, J. B., Chief Chem., Ga. Kraft Co., Macon, Ga.

Bragstad, R. E., City Engr., City of Sioux Falls, City Hall, Sioux Falls, S. Dak.

Brancato, Anthony F., Foreman, 44 Ansonia St., Hartford 6, Conn.

Brechin, W. A., Chem., Gen. Supt. Office, Canada Packers Ltd., 2200 St. Clair Ave., W. Toronto 9, Ont., Canada

Breck, Ted, Opr., Waseca Sewage Disp. Plt., 415 7th Ave., N. W., Waseca, Minn.

Breidefors, O. B., Pub. Health Off., Nassjo stads byggnadskontor, Nassjo, Sweden

Bremser, L. W., Cons. Engr., Black & Veatch, 5031 Pawnee Dr., Kansas City, Mo.

Brewer, Burton, Opr., Boro. of Phillipsburg, 122 Woodlawn Rd., Phillipsburg, N. J.

Bricker, Paul W., Mech. Engr., Gannett Fleming Corddry & Carpenter, Inc., 600 N. 2nd St., Harrisburg, Pa.

Briddle, Carl, Opr., Sewage Trt. Plt., 706½ N. 9th St., Lafayette, Ind.

Bridson, Keith, Pub. Health Engr., Reg. Health Office, Iowa State Dept. Health, Washington, Iowa

Briganti, Theodore, Chief San. Engr., Brown Engr., 10 Columbus Circle, N. Y.

Bright, W. Lloyd, Supt., Sewage Trt. Plt., City of Pittsburg, City Hall, Pittsburg, Calif.

Brill, H. K., see Smith, A. O., Corporation

Brinckerhoff, Gilbert G., Jr., Engr., Gannett Fleming Corddry & Carpenter, Inc., 1646 Cedar Cliff Dr., Camp Hill, Pa.

Brindley, Martin V., Opr., Sewage Plt., Municipal Bldg., Carrollton, Ky.

Bristow, Preston A., Jr., Civ. Engr., Eimco Corp., Box 6047, Birmingham, Ala. (Ga.)

Brosseau, Marc H., Cons. Engr., 1912 Place Eliemre Brulé, Montreal, Que., Canada

Brown, Floyd E., Cons., 119 Howard St., Reading, Mass.

Brown, James C., Proj. Engr., O'Brien & Gere, 220 Cherry Rd., Syracuse 4, N. Y.

Brown, Percy P., Jr., Cons. Rep. for Dr. D. A. Okun, Dept. San. Engr., Univ. of North Carolina, 144 St. John's Ct., Rock Hill, S. C. (Va.)

Brown, Wade G., Chem., Water & Sewage Dept., 1317 Arnette Ave., Durham, N. C.

Brown, Walter F., Ind. Waste Control Br., Dept. of Works, Metro. Toronto, 533 Arbor Rd., Port Credit, Ont., Canada

Brubaker, George E., Jr., Town Clerk, Town Hall, Winthrop, Iowa

Brunn, Philip A., Jr., Mgr., Philip A. Brunn, Jr., San. Div., Ingomar, Pa.

Bryant, Virgil F., Jr., Civ. Engr., 375 N. Crescent Dr., Melbourne, Fla.

Bryant, Wayne E., Supt., Woodridge Sewer & Water Co., 2921 Forest Glen, Downers Grove, Ill.

Buescher, Charles A., Jr., 6354 Henner, St. Louis 20, Mo.

Bulger, Ernest N., Sales Engr., 1160 Thomas Rd., Wayne, Pa.

Bull, L. M., C. C. Parker & Assoc., Ltd., 795 Main St. W., Hamilton, Ont., Canada

Bullard, Clarence, Box 16, Auburn Univ., Loachapoka, Ala.

Burant, Walter, Jr., Grad. Stud., Univ. of Wisconsin, 303 W. High St., Urbana, Ill.

Burbank, Nathan C., Jr., 131 Sweetbriar La., Kirkwood 22, Mo.

Burch, Harvey D., Sewage Foreman, Dothan Engr. Dept., Dothan, Ala.

Burch, James E., Engr., Jerome Richardson & Assoc., RR 3, Loogootee, Ind.

Burcham, Frank, Opr., Sewage Trt. Plt., City of Colville, Rt. 3, Colville, Wash.

Burchfield, A. Myler, 1004 4th Ave. W., Birmingham, Ala.

Burchinal, Jerry C., Assoc. Prof., Civ. Engr. Dept., West Virginia Univ., Morgantown, W. Va.

Burgess, J. Edward, Jr., Biol., Fla. State Bd. of Health, Box 944, Winter Haven, Fla.

Burkhardt, Howard L., Ind. Hyg. Engr., Southeastern Dist. Health Dept., 115 N. 6th St., Pocatello, Idaho

Burns & McDonnell Engr. Co., Box 173, Kansas City 41, Mo.

Burrons, M. E., General Electric Co., Hickory, N. C.

Burroughs, Donald E., R. W. Beck & Assoc., Columbus, Nebr.

Buscavage, John J., San. Engr., Pa. Dept. of Health, 29 Chestnut St., Lewistown, Pa.

Bush, Harry L., Supt., Pub. Works, Village of Paw Paw, Paw Paw, Mich.

Bush, O. R., Supt., Fallbrook San. Dist., Box 697, Fallbrook, Calif.

Bussells, William J., Turpin, Wachter & Assoc., 126 West St., Annapolis, Md.

Bussey, John, Opr., Village of Milford, 124 E. Commerce St., Milford, Mich.

Butkus, R., Southland Frozen Meat & Produce Export Ltd., Box 834, Invercargill, New Zealand

Butler, E. W., Butler & Assoc., 8515 Delmar Blvd., St. Louis 24, Mo.

Byers, John M., Rep., Schmieg Ind., Inc., Box 605, Flint 1, Mich.

Bylicki, Klemens, San. Engr., W. F. Schade & Assoc., 3828 E. 54th St., Cleveland 5, Ohio

C. & C. Construction Co., Inc., Att.: Harry E. Curtis, 4625 Industrial Rd., Fort Wayne, Ind.

Cajigas-Llamas, Carlos E., Design Engr., P. R. Water & Sewer Auth., Box 581, Hato Rey, Puerto Rico

Calder, William G., Pres., Joints, Inc., 5669 Selmaraine Dr., Culver City, Calif.

Caldwell, Bongkee K., Grad. Stud., Univ. of Kentucky, Box 5554, Lexington, Ky.

Calhoun, Taylor P., Chief Opr., Sewage Trt. Plt., City Hall, Hollywood, Fla.

Calkins, Gerald P., Supt., Sewage Trt. Plt., 903 S. Silver St., Centralia, Wash.

Campbell-Little, N., A. P. I. Cotterell & Sons, 54 Victoria St., London, S. W. 1, England (IPHE)

Candish, A., Engr., Thomas Borthwick & Sons Ltd., Box 2598, Wellington, New Zealand

Cannon Arnold M., Supt., Combined Util., City of Clinton, Box 283, Clinton, S. C.

Capis, John G., Asst. Plt. Opr., Southwest Suburban Sewer Dist., 5246 21st Ave., S. W., Seattle, Wash.

Capps, Vernon, Supt., Pub. Works, City of Central Point, 636 Oak St., Central Point, Ore.

Capriola, George H., Supt., Plt. & Pipe Lines, Devon Drainage Assn., Box 842, Devon, Pa.

Carlson, Gustaf, Design Engr., Alexander Potter Assoc., 174 Candee Ave., Sayville, N. Y. (N. J.)

Carnes, Claude C., Chief Chem., San. Dist. No. 1 of Campbell & Kenton Co., 212 Greenup St., Covington, Ky.

Carol Stream Utilities Co., 1325 N. Main, Wheaton, Ill.

Carrington, Kenneth E., Acting Chief Opr., City Sewage Trt. Plt., 12 Wheeler Ave., Cortland, N. Y.

Carroll, R. C., Jr., Mgr., Bd. of Pub. Works, Gaffney, S. C.

Carty, James M., Foreman, Asst. Opr., Boro. of Phillipsburg, 17 W. Thompson Ave., Pleasantville, N. J.

Caruso, Vito J., Assoc., Nussbaumer, Clarke & Velzy, 442 Potomac Ave., Buffalo 13, N. Y.

Carver, Paul T., San. Engr., Charles A. Maguire & Assoc., Turkshead Bldg., Providence, R. I.

Casey, Thomas J., San. Engr., Partner, Angus Henderson, 330 Winthrop St., Westbury, L. I., N. Y.

Casparian, Robert, E. F. Drew & Co., Inc., Box 119, Boonton, N. J.

Caswell, J. D., 124 E. Commerce St., Milford, Mich.

Caswell, Keith P., Jr., Pres., Caswell Engr. Co., 1318 Valders Ave., Minneapolis, Minn.

Cates, Reuben, see Board of Public Utilities

Cator, Ward F., Sales Engr., Fluid Controls Co., Inc., 5150 Ridge Ave., Philadelphia 28, Pa. (N. J.)

Cawley, William A., San. Engr., Res. Dept., Mead Corp., Chillicothe, Ohio

Cepero-Brewer, Frank, Cons. Engr., Commonwealth Laboratiores, Box 281, Hato Rey, Puerto Rico

Cerra, Frank, Vice-Chairman, Pub. Util. Comm., 47 Estelle St., Saulte Ste. Marie, Ont., Canada

Chapman, Floyd A., see Pacific Pumping Co.

Chapman, John, Supt., Water & Sewer Dept., Hurricane, W. Va.

Chapman, Maro H., Jr., Cons., 125 Dauntless La., Hartford 6, Conn.

Cheney, John Guy, Jr., Supvr., Facilities & Mech. Design, Box 8013, Orlando, Fla.

Chiarovano, Robert B., Stud., Univ. of Washington, 804 S. Puget Sound St., Tacoma 6, Wash.

Chipman, S. G., Pres., S. G. Chipman & Co., Ltd., Cons. Engr., 234 Queen's Ave., London, Ont., Canada

Christensen, George C., Chem., Norristown Water Co., 112 W. Main St., Norristown, Pa.

Chumard, Geary W., Owner, Chumard & McLouch, 4 Fairlawn Ave., Middletown, N. Y.

Clapp, Milton, Jr., 237 Tranquil Ave., Charlotte, N. C.

Clark, A. F., Supt., Util., Box 228, Waverly, Ohio

Clark, Gordon E., Mfr., 109 Kings Hwy. S., Darien, Conn.

Clark, J. C., Tech. Supt., Bowaters Carolina Corp., Box 351, Catawba, S. C.

Clark, Joseph R., Assoc., Parsons, Brinckerhoff, Quade & Douglas, 165 Broadway, New York, N. Y. (N. J.)

Clark, Lawrence B., C. & O. Rwy. Co., Box 1254–1255, Richmond, Va. (Ala.)

Clay Pipe Institute, Att.: J. J. Stein, Sec.-Mgr., 445 9th St., San Francisco 3, Calif.

Cleland, Ralph R., San. Engr., Pa. Dept. of Health, Box 90, Harrisburg, Pa.

Clesceri, Nicholas L., Res. Asst., Grad. Stud., Univ. of Wisconsin, San. Lab., Madison 6, Wis.

Clista, Theodore P., San. Engr., Pa. Dept. of Health, 996 S. Main St., Meadville, Pa.

Clock, Leon, Supt., Trt. Plt., Iowa Boy's Training School, Eldora, Iowa

Coddington, Richard A., Dist. Pub. Health Engr., State Dept. of Health, City Hall, Mitchell, S. Dak.

Coffey, L. E., Mgr., Arlington Util. Co., 5708 Van Buren, Arlington, Calif.

Colby, George H., Gen. Foreman, 26 Dowd St., Newington, Conn.

Cole, Richard F., San. Engr., 843 E. Ontario St., Philadelphia 34, Pa.

Coleman, John C., Civ. Engr., W. S. Dickey Clay Mfg. Co., Box 4365 Station A, San Antonio 7, Tex.

Coles, Wilbur G., Plt. Opr., Bunker Hill, Sta. 1, Box 1365, Coos Bay, Ore.

Colley, Darrell, Vice-Pres., Colley & Schlee, Inc., Box 55, Southfield, Mich.

Collins, John H., American-Marietta Co., Box 1629, Albuquerque, N. Mex.

Collins, Paul J., Sec., Gulf Homes Water Corp., 539 Caillavet St., Biloxi, Miss.

Coloney, Wayne H., Proj. Engr., J. E. Greiner Co., Inc., 207 Franklin St., Tampa 2, Fla.

Compisi, Frank A., Supt., Water & Sewer Dept., Orchard Pl., North Collins, N. Y.

Connolly, Hugh H., Asst. Area Engr., PHS, Div. of Indian Health, Box 2143, Billings, Mont.

Continenza, Ralph, Supt., Wastewater Trt., 5141 Richmond Rd., Bedford Hts., Bedford, Ohio

Contreras-Munoz, Victor L., Design Engr., P. R. Water & Sewer Auth., Box 281, San Lorenzo, Puerto Rico

Cook, Charles E., San. Engr., State Bd. of Health, 10643 Lakeview Rd., E., Jacksonville 11, Fla.

Cook, Eugene M., Jr., San. Sales Engr., Dorr-Oliver Inc., 18 Nolan St., Norwalk, Conn.

Cooper, Arthur S., Jr., Bur. of San. Sewers, 6th Floor, City Hall, Tampa 2, Fla.

Cooper, D. E., Asst. Chem., Auckland Farmers Freezing Co., Box 90, Auckland, New Zealand

Copland, Robert P., Gen. Mgr., Vice-Pres., Canada Valve & Hydrant Co., Ltd., 162 Norman St., Waterloo, Ont., Canada

Coppola, Tom T., Opr., City of Pinconning, 208 S. Manitou, Pinconning, Mich.

Cord, Robert S., Resident Insp., Sewage Trt. Plt., City Hall, Shelbyville, Ind.

Corley, Earl W., Mgr., Harris Co. W. C. & I. D. 35, Box 207, Seabrook, Tex.

Cornett, Jack, 3122 S. Winston, Tulsa, Okla.

Corrosion Control Co., Inc., Att.: Joseph C. Roach, Vice-Pres., 33 W. 42nd St., New York 36, N. Y. (Assoc.)

Cotterell, Jerry, see Idaho Falls, City of

Cotton, D. J., Canada Valve & Hydrant Co., Ltd., 12247 Dover Court Cresc., Edmonton, Alta., Canada

Coulling, Oliver G., Supt., Augusta Sewerage Dist., 25 Wade St., Augusta, Me.

Courchaine, Robert J., San. Engr., Mich. Water Resources Comm., 318 Jones St., Lansing 12, Mich.

Covey, Harry E., Engr., 40 Dorlen Circle, Wethersfield, Conn.

Cowan, Richard S., Cons. Engr., 3 Mile Run Rd., MR 1, Perkasie, Pa.

Cox, T. S., Plt. Opr., City Disp. Plt., Florence, S. C.

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WATER POLLUTION CONTROL FEDERATION

CONSTITUTION AND BYLAWS

Adopted January 15, 1941. As amended to December 24, 1959.

CONSTITUTION

ARTICLE I. Name

The name of this organization shall be the Water Pollution Control Federation, hereinafter designated as the Federation.

ARTICLE II. Objectives

The objectives of this Federation shall be: The advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes; the design, construction, operation and management of sewer systems and treatment works; the study, promotion and encouragement of improved sanitation of waterways; the correlation and strengthening of regional and state sewage and industrial wastes associations or conferences within or without the United States of America; the publication of a journal; and other relevant activities.

ARTICLE III. Membership

The membership of the Federation shall consist of regional or state associations or conferences, either within or without the territory of the United States of America, hereinafter designated as Member Associations, whose objectives and constitutions are in harmony with the purposes of this Federation, and of individuals or corporations as specified in the Bylaws, subject to the conditions and limitations prescribed in the Constitution and Bylaws of the Federation.

ARTICLE IV. Organization

SECTION 1. The affairs of the Federation shall be conducted by a Board of Control (hereinafter designated as the Board) under such rules as the Board may determine, subject to the specific conditions of this Constitution and Bylaws.

SECTION 2. The officers of the Federation shall be a President, a Vice-President, a Secretary, and a Treasurer.

SECTION 3. The Board shall consist of:

(a) The President of the Federation.
(b) The Vice-President of the Federation.
(c) The Treasurer of the Federation.
(d) One Director to be appointed by and to represent each Member Association. One additional Director to be named by each Member Association which has maintained a total Active plus Corporate membership of 500 or more for the three preceding successive years ending on September 30.
(e) Six Directors-at-Large, of whom three are to be elected by the Board of Governors of the Water and Sewage Works Manufacturers Association, and three by the Directors representing the Member Associations.
(f) The latest living Past President of the Federation.

SECTION 4. The terms of office of the President, Vice-President, and Treasurer shall be one year, and the Directors three years, which terms shall start at the beginning of the last session of the Annual Meeting of the Board at which they are elected and continue until a successor qualifies. The Secretary shall be appointed by the Board for the term of office stated in the Bylaws. In the case of a vacancy in the office of President, the Vice-President shall act in his place for the unexpired term. In case the Vice-President cannot act, the latest living Past President shall do so. In the case of a vacancy in the office of Treasurer or of any Director-at-Large representing Member Associations, the Executive Committee shall appoint an Active Member to fill such office for the unexpired term. Any vacancy occurring among the Directors-at-Large elected by the Manufacturers Association shall be filled by the Board of Governors of that Association.

SECTION 5. The President shall be ineligible for re-election. The Vice-President and Directors shall not be eligible for reappointment or for re-election to the same office until at least one full term shall have elapsed after the end of their respective terms.

SECTION 6. The President of the Federation shall be the Presiding Officer of the Board.

SECTION 7. A quorum of the Board shall consist of a majority of its ex-officio members, Directors-at-Large, and those Directors representing Member Associations within the territory of the United States of America and of Canada. Any member of the Board, except the President, Vice-President, or Treasurer may designate a proxy to act for him if he is unable to attend a meeting in person. Such proxies shall be designated in writing by the absentee Board member from the same Member Association, or organization he represents. All such proxies shall be counted in determining a quorum. Only in the event of lack of a quorum at an Annual Meeting shall the chair be authorized to appoint proxies and then only from the absentee Member Association or organization, if such representation is available. In no case shall any individual cast more than one vote.

ARTICLE V. Nomination and Election of Officers and Directors

SECTION 1. The Annual Meeting of the Board shall be held during the Annual Convention of the Federation on such day or days as may be decided by the Board. In event there is no Annual Convention of the Federation the Annual Meeting of the Board shall be in the office of the Federation on the third Saturday in October. Other meetings of the Board may be held as provided in the Bylaws.

At the Annual Meeting the Directors representing the Member Associations shall meet under the chairmanship of the President of the Federation, and shall by a majority vote of all such Directors voting, elect a President, Vice-President, Treasurer and one Director-at-Large. Absent Directors may vote by proxy, in accordance with procedure defined in Article IV, Section 7 of this Constitution. Any candidate so elected shall be an Active Member of some Member Association and shall signify willingness to serve. Any candidate elected as President or Vice-President shall at some time previous to such election have been a member of the Board of Control.

SECTION 2. One Director on the Board of Control to represent each Member Association shall be elected by each Member Association. One additional Director is to be elected by each Member Association which has maintained a total Active plus Corporate membership of 500 or more, for the preceding three successive years ending on September 30. Each Director so elected shall be an Active Member of the respective Member Association and in good standing at the time of his election.

In the case of any Director, representing a Member Association, retiring for any cause before his term is completed, or who fails to remain in good standing in his Member Association, the governing board of the Member Association shall designate his successor, who shall serve for the unexpired portion of his term.

ARTICLE VI.

Except as specifically mentioned herein, this Constitution shall take effect immediately upon its adoption by the Board of Control.

ARTICLE VII. Amendments

Amendments to this Constitution may be made by a two-thirds vote of the total membership of the Board present or represented by proxy, notice of the proposed amendment having been given to each member of the Board and to the Secretary of each Member Association not less than sixty days in advance of the meeting, at which the said amendments are to be voted upon.

BYLAWS

ARTICLE I. Member Associations

SECTION 1. Any regional or state association or conference, or other organization whose objectives and constitution are in harmony with those of the Federation, may be granted membership in the Federation by a majority vote of the Board; provided, that the constitution of the applicant association or conference has been examined and certified by the Board as being in accord with Article III of the Constitution of this Federation; and provided further, that certification shall be made by the association seeking admission to membership that the Constitution and Bylaws of the Federation are accepted by it.

SECTION 2. If a group of Active and Corporate Members affiliated with the Federation is part of an organization which has an interest in major fields other than sewage and industrial wastes, this group shall be established as the sewage and industrial wastes section of the organization and shall have its own constitution and bylaws provisions. The section shall be considered the official Member Association of the Federation. The officers and Director to the Federation of such section shall be Active Members. All officers of this section shall be elected by the section membership. The section or its executive committee shall have at least one meeting per year.

SECTION 3. Member Associations may affiliate with or establish other associated groups as an adjunct to its over-all coverage of the sewage and industrial wastes field. Classification of membership for such affiliates shall be determined by the Member Association but shall not include Associate Members or Sustaining Members which classes of membership are reserved to the Federation. The affiliated groups shall be represented on the Executive Committee of the Member Association. The affiliate's President or Chairman, its Secretary, and its representative to the Member Association shall be Active Members.

SECTION 4. Any Member Association may withdraw from the Federation at the end of any fiscal year by giving three months' notice of such intention, provided that the dues of such Member Association in the Federation are fully paid up to time of withdrawal.

SECTION 5. Any Member Association may be excluded from this Federation, at the pleasure of the Board, for non-payment of dues, as hereinafter provided, or for any change in its constitution that may bring it into conflict with the Constitution or Bylaws of the Federation.

SECTION 6. Any change in the existing constitution or bylaws of a Member Association shall be reported in full to the Secretary of the Federation within thirty days after its adoption by said Member Association.

ARTICLE II. Classification of Members

SECTION 1. Membership of the Federation shall be composed of Member Associations, Honorary Members, Associate Members and Sustaining Members. Membership in the Member Associations shall consist of Active Members, Corporate Members and such other members as shall be determined by the Member Association and as provided for in Article I, Section 3 of the Bylaws. Only Active Members and Corporate Members shall be certified to the Federation.

SECTION 2. Without changing the basic concept of Federation membership, an Active or Corporate Member may identify himself as a member of the Federation.

SECTION 3. An Active Member shall be a superintendent, manager, operator, or employee of a sewage or industrial wastes system or treatment works; a professional engineer; a chemist, bacteriologist, biologist, or any qualified person professionally engaged or interested in the advancement of knowledge relating to the disposal or treatment of sewage and industrial wastes or improved sanitation of waterways.

SECTION 4. A Corporate Member shall be a Sewerage Board, Department or Commission; Sanitary District; Department of Public Works handling sewerage; Industrial Corporation; National, State, District or Municipal Board or Department of Health; or other body, corporation or organization engaged or interested in at least one of the stated objectives of the Federation, and shall be entitled to one representative whose name shall appear on the roll of members and who shall have all the rights and privileges of an Active Member. This representative may be changed at the convenience and pleasure of the Corporate Member on written notice to the Secretary of the Member Association to which the Corporate Member is accredited.

SECTION 5. An Honorary Member shall be a person of acknowledged eminence in one or more fields of activity within the scope of the stated objectives of the Federation. Candidates may be nominated by any Member Association or by a special committee appointed by the Board but can be elected only by favorable secret ballot vote of the Board. Two negative votes shall exlude. No election to Honorary Membership shall be made which would cause the total number of Honorary Members to exceed a ratio of one Honorary Member to every 350 Active Members. Not more than two Honorary Members shall be elected in any calendar year. Honorary Members shall be elected for life, shall pay no dues, and shall receive, without cost, all the publications of the Federation that are distributed to its members.

SECTION 6. An Associate Member shall be a person, firm, or corporation engaged in the manufacturing or furnishing of supplies, materials, or equipment for the construction, operation or maintenance of sewage or industrial waste facilities, and shall be elected by affirmative vote of a majority of the Board after consideration of written application duly made to the Secretary.

SECTION 7. A Sustaining Member shall be an individual or a corporation interested in the general objectives of the Federation.

ARTICLE III. Dues

SECTION 1. The status and dues of the different classes of members established by the Member Associations, as applied to their members, shall be as determined by the Member Association.

SECTION 2. (a) For each Active Member the annual dues shall be as determined by the Board, payable in advance by the Member Associations to the Secretary of the Federation.

(b) For each Corporate Member the annual dues shall be as determined by the Board, payable to the Secretary of the Federation by February 1 of each year.

(c) For each Sustaining Member and each Associate Member the annual dues shall be as determined by the Board, payable to the Secretary of the Federation by February 1 of each year.

(d) Corporate Members, Sustaining Members, or Associate Members whose dues remain unpaid on March 1 of any year may be dropped from membership on action of the Executive Committee.

(e) The dues for Member Associations outside the United States of America and its territorial possessions shall be greater than the amounts hereinbefore specified by an amount to be fixed annually by the Board as equivalent to the added cost for mailing the Journal to such associations as compared with the average cost for mailing to members residing within these limits.

(f) Active Members, paying full dues, and Corporate Members of Member Associations, and Associate and Sustaining Members of the Federation, in good standing, shall be entitled to one copy each of all publications that are distributed by the Federation to its members.

SECTION 3. The fiscal year of the Federation shall begin on January 1, and annual dues shall be collectible on that date and shall have been paid before February 1. If the dues of any Member Association shall not have been paid by February 1, fifteen days notice of the dues in arrears shall be given to that association, after which time, if the dues remain unpaid, that association may be dropped from the rolls of the Federation on action by the Board, as provided in Article I, Section 3, of these Bylaws.

SECTION 4. Any member, newly elected before June 30, shall pay full dues and shall be entitled to all the publications of the Federation that are distributed to its members during the year. Members elected after June 30 shall pay one-half the regular dues for that year, and shall be entitled to all of the publications distributed during the half year beginning July 1.

SECTION 5. In transmitting dues to the Federation, each Member Association shall forward with them a list of the names, professional titles and correct mailing addresses of all members of all classes of the said Association who are in good standing and are entitled to receive the Journal or other distributed publications of the Federation during the ensuing year.

ARTICLE IV. Duties of Officers and Directors

SECTION 1. The President shall have general supervision of the affairs of the Federation, and shall preside at all conventions of the Federation and meetings of the Board. In his absence the Vice-President shall preside. Should both be absent the Board shall elect the Presiding Officer. The President shall be, ex-officio, a member of all committees.

SECTION 2. The Vice-President shall assist the President in the performance of his duties, and act in his stead when required.

SECTION 3. The Board of Control shall be the legal representative of the Federation, and as such shall manage its affairs subject to the conditions and limitations prescribed in the Constitution and Bylaws; direct the investment and care of funds of the Federation; make appropriations for specific purposes; appoint employees and fix their compensation; take measures to advance the interests of the Federation; and generally direct its business. The Board shall not incur indebtedness beyond the funds in the hands of the Treasurer and the Secretary. The Board shall hold a meeting during the Annual Convention. Other meetings shall be held at the call of the President, or on petition addressed to the Secretary and signed by ten or more members of the Board representing not less than seven Member Associations. Notice of all meetings shall be issued by the Secretary at least fifteen days in advance of such meetings to all members of the Board and to the Secretary of each Member Association. In the event of a vacancy in the office of Secretary, notices of meetings will be issued by the President.

At the Annual Meeting the Board shall appoint a Secretary to serve for a term of two years, unless removed for cause by the Board.

Except as otherwise provided in the Constitution and Bylaws, all questions before the Board shall be decided by a majority vote of those present.

SECTION 4. The Treasurer shall have charge of the funds of the Federation and custody of its investments, if any. He shall pay bills against the Federation when certified by himself and the Secretary. He shall make a report for each calendar year at the Annual Meeting of the Board, showing receipts from the Secretary and other sources, the expenditures, the investments and other assets, and the liabilities of the Federation. He shall make such other reports as may be required by the Board.

He shall be bonded at the expense of the Federation, and to an amount to be determined by the Board.

He shall perform such other duties as may be assigned to him by the Board.

SECTION 5. The Secretary shall be an Active Member and, under the direction of the President and the Board of Control, shall be the executive officer of the Federation. It shall be his duty to attend all conventions and meetings of the Board, prepare the business and duly record the proceedings thereof. He shall see that all monies due the Federation are carefully collected and without loss transferred to the custody of the Treasurer. He shall scrutinize all expenditures, shall certify to the accuracy of all bills and vouchers on which money is to be paid, and shall countersign checks drawn by the Treasurer against the funds of the Federation when such drafts are known by him to be proper and duly authorized by the Board. Once every three months he shall forward to each member of the Board a financial summary of receipts and disbursements, and at the Annual Meeting of the Board shall present a balance sheet of his books as of the 31st of December and as of the 30th of September preceding the meeting, together with a report of the activities of his office.

He shall have charge of the books and records of the Federation, including lists of members of the Federation and subscribers to the Journal. He shall have charge of the mechanical production and distribution of the Journal and other publications of the Federation, and shall handle all financial matters connected therewith.

He shall be bonded at the expense of the Federation, and to an amount to be determined by the Board.

The books of the Federation shall be audited annually at the expense of the Federation by public accountants to be appointed by the Board.

In the event that the Secretary or Treasurer shall be unable to sign checks against the funds of the Federation, the President or Vice-President shall be authorized to countersign such drafts in his stead.

SECTION 6. The Secretary shall serve as Editor of all publications of the Federation and shall receive all manuscript copy and prepare it for publication. He shall have the authority to return to the author for correction, or to reject entirely, any manuscript which may be in bad condition, illegible, or clearly deficient in respect to composition, subject matter or supporting data, or otherwise conspicuously deficient or unfit for publication. He also shall have the authority to reject any manuscript which is designed to promote commercial interests. He shall be a member of the Publications and Program Committee and of the Committee on Sewage and Industrial Wastes Practice. Decisions of the Editor relative to rejection of manuscripts shall be subject to appeal to the Publications and Program Committee.

ARTICLE V. Conventions of the Federation

The Annual Convention of the Federation shall be held at a time and place selected by the Board, preferably in the month of October. All conventions and meetings shall be conducted according to "Roberts Rules of Order," except where provisions to the contrary are noted in any Article herein.

Each member and guest present at any of the conventions of the Federation shall pay a registration fee of such amount as may be determined by the Executive Committee.

ARTICLE VI. Committees

SECTION 1. There shall be an Executive Committee of seven members consisting of the President, Vice-President, immediate Past President and four Directors. This committee shall be chosen by the Board at its Annual Meeting. The President of the Federation shall be Chairman, and the Secretary of the Federation shall act as Secretary of the committee. In the absence of the President, the Vice-President shall preside. The duties of this committee shall be to direct the administrative work of the Federation and carry out the policies of the Board between meetings of the latter. A quorum of the committee shall be four members.

SECTION 2. A Publications and Program Committee shall be appointed by the Board at its Annual Meeting. It shall consist of the Secretary and four or more Active Members of which at least three shall be Members-at-Large. The Publications and Program Committee shall arrange the technical programs for the Annual Convention of the Federation. The committee shall prepare general rules which, after approval by the Board, shall control the preparation, presentation, acceptance and publication of papers and shall have general supervision of such other matters of similar nature as the best interests of the Federation may require.

SECTION 3. An Organization Committee of five Active Members of which at least three shall be Members-at-Large shall be appointed by the Board at the Annual Meeting. The Organization Committee shall examine and report to the Board on application for membership in the Federation and also serve in the encouragement of the formation of new regional or state associations or conferences eligible for membership, as well as serving in an advisory capacity in other matters of a similar nature as the best interest of the Federation may require.

SECTION 4. A Sewage and Industrial Wastes Practice Committee consisting of the Editor and four or more Active Members of which at least three shall be Members-at-Large shall be appointed by the Board at the Annual Meeting.

Any publication which undertakes to establish in the name of the Federation, professional or technical standards shall be submitted by this committee to the Board for approval.

It shall give notice by publication to the membership of all such approved standards and publications.

It shall appoint such subcommittees as it may deem necessary to carry on its work.

SECTION 5. There shall be a Research Committee of five or more Active Members of which at least four shall be Members-at-Large.

The Research Committee shall be charged with the duty of stimulating and coordinating research work among the various Member Associations, and of cooperating with other organizations in the promotion of research work.

SECTION 6. There shall be a Finance Committee of five members consisting of the President, the latest living Past President, the Treasurer, and two Members-at-Large, one of whom shall be appointed Chairman and the other Vice-Chairman. The committee shall present at the Annual Meeting of the Board a budget of estimated expenses of the Federation, including publications, for the ensuing year. On the adoption of the budget by a majority vote of the Board members present, expenses of the Federation shall be limited, as far as may be practicable, within the amounts prescribed in said budget.

The committee shall also function in a general advisory capacity to the Board and to the Executive Committee in all matters relating to finances of the Federation.

SECTION 7. There shall be a Committee on Standard Methods of Sewage and Industrial Wastes Analysis of five or more Active Members of which at least four shall be Members-at-Large.

The committee shall be charged with the duty of developing, perfecting and modifying standard methods for the analysis of sewage and industrial wastes and of sludges or

by-products therefrom, and of cooperating with other organizations interested and engaged in similar work.

SECTION 8. There shall be a Committee on Industrial Wastes consisting of five or more Active Members of which at least four shall be Members-at-Large.

The committee shall be charged with the duty of stimulating interest in, and of being of service to industry in the varied problems encountered in the industrial wastes field, including cooperation between Member Associations, and other organizations and agencies.

SECTION 9. Each of the Committees listed in the preceding Sections shall at the time of appointment, include a Vice-Chairman.

SECTION 10. All of the Chairmen and members of the Committees named in Sections 2, 3, 4, 5, 6, 7 and 8, of this Article shall be appointed annually by nomination of the President and confirmation by the Board of Control. The Chairmen shall sit in meetings of the Board of Control with full privilege of discussion. None of these Chairmen shall serve more than five years in succession.

SECTION 11. There shall be a General Policy Committee consisting of the President, the three preceding living Past Presidents; and one member representing the Water and Sewage Works Manufacturers Association. The member of the Committee representing the Water and Sewage Works Manufacturers Association shall be nominated by that Association's Board of Governors subject to acceptance by the Board of Control. The Chairman of the General Policy Committee shall be the immediate Past President of the Federation, who is, ex-officio, a member of the Board.

The General Policy Committee shall consider subjects referred to it by the Board, by the Executive Committee of the Board, or by the President; which subjects have to do with general or long-term policies of the Federation.

The recommendations or statements of policy formulated by the General Policy Committee upon any question referred to it, shall be reported to the Board for consideration and further action.

SECTION 12. There shall be a Committee on Nominations consisting of the five latest living Past Presidents, the senior member of which, in point of service, shall serve as Chairman.

SECTION 13. The Board shall appoint such other committees as may be necessary to carry on the work of the Federation.

SECTION 14. The reports and recommendations of all committees of the Federation shall be subject to approval by the Board.

SECTION 15. Members-at-Large are Active Members who are not members of the Board.

ARTICLE VII. Publications

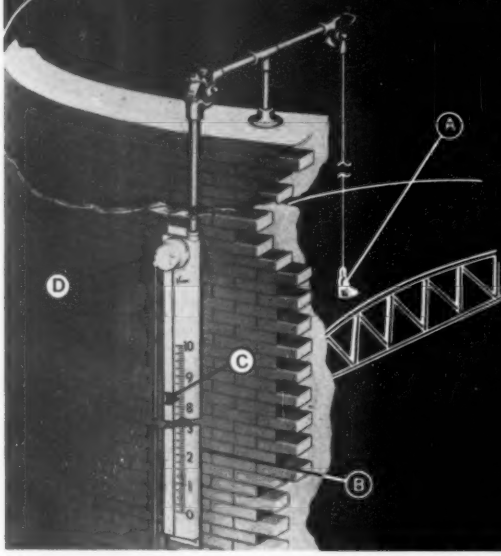
All publications of the Federation shall be issued under the direction of the Board and shall be copyrighted as far as is practicable and proper.

ARTICLE VIII. Amendments

The Board of Control may amend these Bylaws in any manner not inconsistent with the Constitution by the two-thirds vote of those voting at any meeting of the Board or by sealed letter ballot, providing that a copy of such proposed amendment has been mailed by the Secretary to each member of the Board and to the Secretary of each Member Association at least thirty days prior to such meeting or letter ballot.

VAREC INDICATOR

A SIMPLE, ACCURATE METHOD FOR INDICATING DIGESTER COVER POSITION



(A) Steel cable that runs from cover connection to counter-weight powered working mechanism

(B) Gauge Board

(C) Red Pointer

(D) Electrical high-low limit switch—in explosion-proof housing—used to actuate alarms (optional).

Varec's economical gauge board indicator accurately gauges the movement of floating cover digesters with a simple working mechanism... displays readings on a 12-foot, easy-to-read anodized aluminum gauge board installed directly outside the digester.

The calibrated gauge board shows measurements in feet and inches... has a 10-foot range with an extra 2 feet of pointer measurement for greater cover or overflow travel. It provides 'quick-at-a-glance' reading with a bright red pointer that contrasts sharply against the white aluminum board and large, black numerals. All parts are ruggedly constructed and the working mechanism is enclosed in a protective housing.

VAREC OFFERS POSITION INDICATORS FOR ALL DIGESTER COVER NEEDS...

Other Varec cover position indicators include a dial type indicator that registers indication within a 10-foot range on a large, easily read dial and can be equipped with alarm switches. And, for remote control reading, Varec provides a highly-accurate gauge head indicator that delivers gauging accuracy to ½ inch... adapts for use with electrical or pneumatic remote reading or control equipment.

For complete information on all Varec digester cover position indicators, write for Varec Catalog No. S-4, Dept. JWP-1221-5

"Varec" TRADE ⊕ MARK

THE VAPOR RECOVERY SYSTEMS COMPANY
2820 North Alameda Street • Compton, California
Branches and Representatives in Principal Cities

PROCEEDINGS OF MEMBER ASSOCIATIONS

NEW ENGLAND SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 32nd Annual Meeting of the New England Sewage and Industrial Wastes Association was held at the Hotel Taft, New Haven, Conn., on Oct. 26–27, 1960. Attending were 150 members and guests, and 13 ladies.

The technical program included these papers: "Hamden Sewage Metering and Recent Changes at the New Haven Sewage Treatment Plant," by William Bolton, City Engineer, New Haven, Conn.; "Application of Closed-Circuit Television in Sewage Treatment Plants," by Robert Berman, President, Magna Film Productions; "Sewage Oxidation Ponds in Derry and Jaffrey, N. H.," by Darrell A. Root, Partner, Camp, Dresser and McKee; "Puddling Trench Backfill," by James J. Malloy, Construction Engineer, Hartford Metropolitan District; "Sludge Density Analyzer," by Keith Tozier, Industrial Nucleonics Corp.; and "Industrial Lubricants in Sewage Treatment Plants," by Richard N. Pigeon, Texaco Inc.

At the business session, the important business of changing the Association's name was transacted. By unanimous vote the name is now: New England Water Pollution Control Association.

Federation Vice-President Harry Schlenz presented the Bedell Award

(*Continued on page 144a*)

SEWAGE TREATMENT PLANT OPERATOR

Sewage treatment plant operator to be responsible for the operation of a 1.5 mgd secondary-type sewage treatment plant with pumping station, primary and secondary sedimentation, trickling filter, contact tank, heated sludge digesters and sludge drying beds; located in Morris County, New Jersey.

Previous experience in this type of plant operation required; must qualify as Grade A operator in New Jersey. Salary open—depending on qualifications.

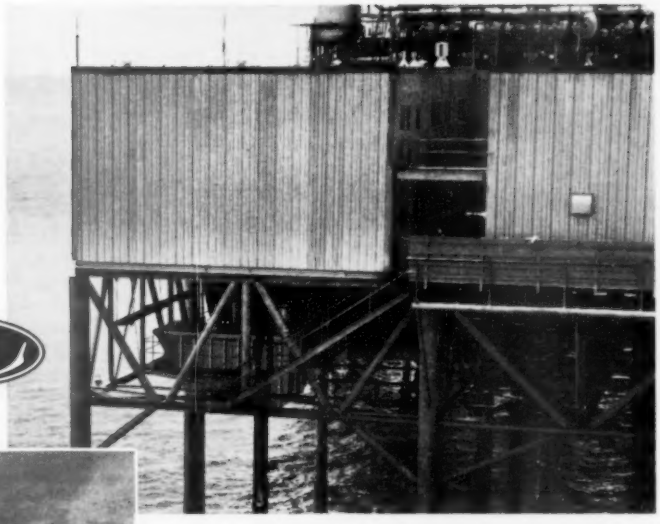
Send resumé containing personal history, experience and educational record to:

HANOVER SEWERAGE AUTHORITY
Harold R. Keenan, Administrator
Box 247 Whippany, New Jersey

TECHNICAL EDITOR

Career opportunity as technical editor in wastewater field. Duties are primarily concerned with well-established and authoritative monthly, located in the East. Must be trained sanitary engineer having first-hand familiarity with treatment plants. Editorial experience desirable but not necessary. Editorial interest and aptitude essential. Interesting and challenging work with growing organization. Send resumé containing personal history, experience, educational record, and salary requirement to:

Box T, JOURNAL WPCF
4435 Wisconsin Avenue
Washington 16, D. C.



S&L

FREEPORT SULPHUR MINE is the world's most unusual mining operation. The above photograph shows the giant water heating plant (left), the hotel-office structure and heliport (center) and the bleedwater platform (background). The sulphur drilling platform with its connecting freeway is pictured below.

Grand Isle

A Smith & Loveless "Oxigest" factory-built sewage treatment plant serves the fabulous Freeport Sulphur Mine located seven miles out in the Gulf of Mexico, off Grand Isle, Louisiana. This unusual treatment plant installation is a 6,000-gallon unit, engineered to serve the disposal needs of the 100-man working force on Freeport's man-made steel island, the world's first off-shore sulphur mining operation.

The Freeport "Oxigest" was shipped by truck from the Smith & Loveless manufacturing plant to Orange, Texas, where it was bolted in place below the superstructure which houses the hotel and office building. Then, the stilt-like structure was floated by barge to the mine site, lifted by huge cranes and set into place, some 60 feet above the Gulf surface.

We, at Smith & Loveless, are proud to count the sewage treatment plant at the Freeport Sulphur Mine among our many "Oxigest" installations.

For more information on Smith & Loveless "OXIGEST" . . . write Department 30.

Smith & Loveless

ONE OF THE UNION TANK CAR COMPANIES

P.O. BOX 8884 / KANSAS CITY 15, MISSOURI / PLANT: LENEXA, KANSAS

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SNOW GATES
for
SEWAGE TREATMENT PLANTS

All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

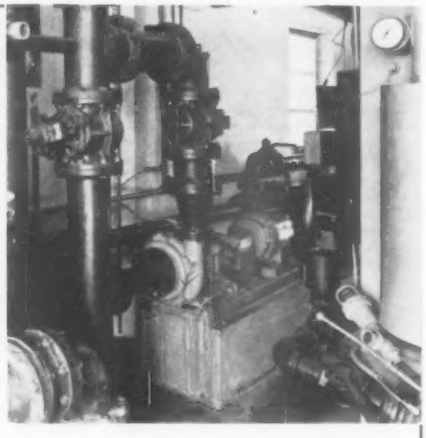
Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

SNOW GATES & VALVES

2437 East 24th Street Los Angeles 54, Calif.

NAGLE TYPE "HR" PUMPS PROVIDE DEPENDABLE CIRCULATION OF SLUDGE THROUGH HEAT EXCHANGERS at East Moline, Ill., Plant.

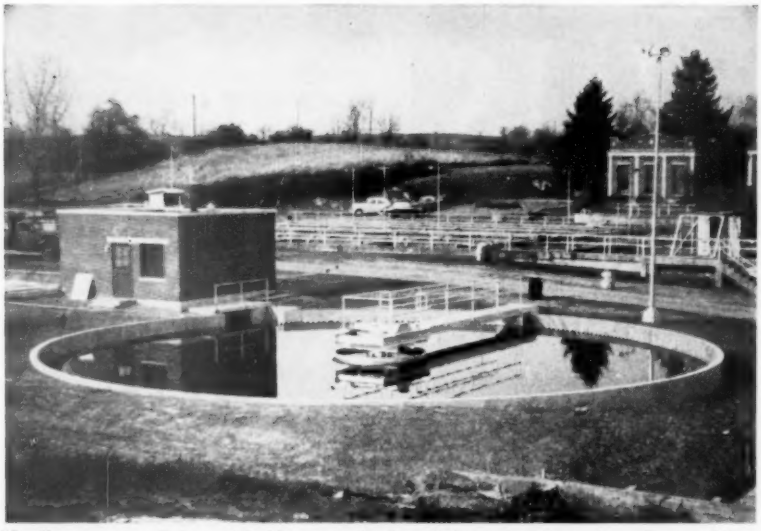


NAGLE Pumps for abusive applications exclusively, are functioning admirably at numerous sewage treatment and water treatment plants. The pump shown, a 3" type "HR", is ideal for handling sludge—one of those in use at East Moline for circulating sludge from digesters through heat exchangers, to maintain the sludge at optimum temperature. The "HR" has a packing gland with trouble "designed out." Simple slippage seal adjustment. Casing and impeller of manganese steel to resist abuse. A soundly engineered pump for years of service, as many users will verify. Send for Nagle Pump Selector. Nagle Pumps, Inc., 1210 Center Avenue, Chicago Heights, Ill.

Tough jobs call for

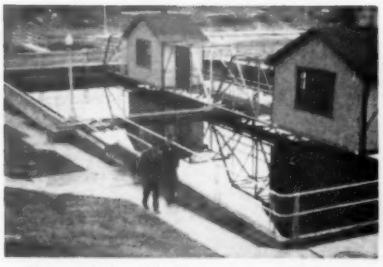
Nagle PUMPS

FOR ABUSIVE APPLICATIONS EXCLUSIVELY



Hardinge Center-Column Clarifier recently installed at the Hagerstown Sewage Plant

another HARDINGE Clarifier for HAGERSTOWN



Original installation: Two Hardinge Rotary Clarifier Mechanisms in rectangular tanks (1932).

Second installation: A Hardinge Beam-Supported Primary Clarifier doing heavy duty (1949).

HARDINGE

COMPANY, INCORPORATED

Main Office and Works • 240 Arch St., York, Pa.

"Hardinge Equipment—Built Better to Last Longer."

NEW YORK
TORONTO
CHICAGO
HIBBING
SALT LAKE CITY
SAN FRANCISCO
HOUSTON
LAKELAND
BIRMINGHAM

KILLS
PSYCHODA FLIES
in trickling filters

kills flies, larvae and pupae

without damage to zoogleal film

without destroying beneficial bacteria

without reducing filter efficiency

NEW INHIBITORY FACTOR—Hundreds of tests have demonstrated that R.S.C. is extremely effective in killing Psychodae which have shown high degree of resistance to DDT, Methoxychlor, Lindane, Chlordane, Dieldrin, Aldrin, Malathion and other insecticides.

This is accomplished by an inhibitory factor which renders a hitherto resistant fly susceptible to the insecticides in the R.S.C. formula. Field tests in such widely separated areas as Illinois, Texas, Florida have shown that use of R.S.C. reduces filter fly population to practically nil.

SAFE, ECONOMICAL—R.S.C. is registered by the United States Department of Agriculture for control of Psychoda flies. When used according to directions, R.S.C. is safe, economical, and the most effective method of filter fly control to date.

Send for literature and field test reports.

R S C T.M.
PAT. APPL. FOR
GLENN
CHEMICAL CO.
Industrial Chemicals Division
CHICAGO 14, ILLINOIS

to Earl R. Howard of the Hartford Bureau of Public Works for his outstanding service to the Association. The Hatfield Award for excellence in treatment plant management was presented to Steven A. Stankey, Superintendent, Fairfield, Conn.

Officers elected for 1960–61 are:

President: Joseph B. Hanlon, Quincy, Mass.
1st Vice-President: Howard Carpenter, Providence, R. I.
2nd Vice-President: Earl R. Howard, Hartford, Conn.
Secretary-Treasurer: Richard F. Greeley, Boston, Mass.
Assistant Secretary-Treasurer: John B. Richards, Burlington, Vt.

EARL R. HOWARD
Secretary-Treasurer

KENTUCKY-TENNESSEE WATER POLLUTION CONTROL ASSOCIATION

The 14th Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association was held at the Andrew Johnson Hotel, Knoxville, Tenn., Sept. 12–14, 1960. The meeting was held jointly with the Kentucky-Tennessee Section AWWA. Total registration for the joint meeting was 343 of which 64 were ladies.

During the business session, the name of the Association was changed to the Kentucky-Tennessee Water Pollution Control Association.

Papers of particular interest to members of the Association were:

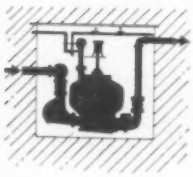
"The Water Pollution Control Federation," by W. D. Hatfield, Past-President, Water Pollution Control Federation, Decatur, Ill.

Panel discussion on "Annexation Problems—Effects on Water and Sewer Systems," with J. Wiley Finney, Jr., partner, Howard K. Bell Engineering Co., Lexington, Ky., serving as discussion leader and the panel

(*Continued on page 148a*)

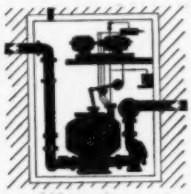
Which sewage lift station is best for your job?

TOPS IN DEPENDABILITY AND SAFETY



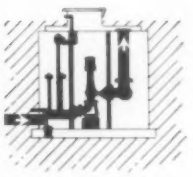
Concrete or steel underground station with Shone® Type S pneumatic ejector, mechanically controlled (warranted 25 years). Remote air supply. Nothing electrical; maintenance free; operates even under water. For municipalities and large subdivisions.

SUPRISINGLY VERSATILE, INEXPENSIVE



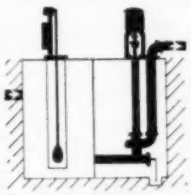
Shone® Type SAC station, underground in concrete vault. Mechanically controlled ejector (warranted 25 years) has its own compressor. Frequently less costly than package stations. Finds use everywhere.

PACKAGE STATION



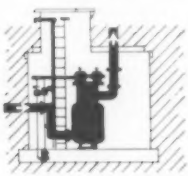
Quality underground station with vertical, short-coupled (Series 6260), dry pit centrifugal pumps. Quality design and equipment give good service life at nominal cost. For small permanent stations, growing areas.

LOW FIRST COST—EASY INSTALLATION



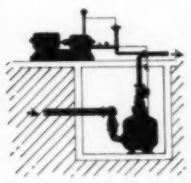
Two-compartment steel basin with centrifugal vertical wet pit pump. Pumps are not submerged; motors protected from flooding. Low first cost; fast installation. For buildings, small growing subdivisions.

ULTIMATE IN PACKAGE DESIGN



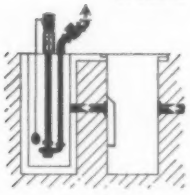
Package underground station with Expelsor® pneumatic ejector, electrode controlled. Sanitary and dependable, low maintenance, easy to service. Recommended for municipal and subdivision applications.

BUILDING TYPE STATION



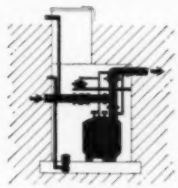
Expelsor® pneumatic ejector station designed for use in buildings. Compressor is on basement floor; ejector on floor below. Sealed installation gives safe, odorless handling of sewage indoors.

SPECIAL PROBLEMS?



Centrifugal vertical wet pit pumps with adjoining settling basin. Good for areas where sand or old sewers create problems. Special pump construction for abrasive or corrosive conditions, industrial wastes.

MAXIMUM RELIABILITY—MINIMUM SPACE



Package underground station. Expelsor® pneumatic ejector has two compartments, duplex compressors and controls. Excellent service accessibility. Especially suited for subdivision and municipal lift stations.

The answer depends on the job. Is it to be a temporary station? What about future loads? How much maintenance will it get? What type of power is available? These and many other questions must be weighed carefully and without bias. In making the decision, why not put Yeomans 61 years' experience (59 on underground stations alone) to work? Because Yeomans builds *the only complete line* of sewage lift stations in the industry, recommendations are *impartial* and in your best interest. Phone, wire, or write now.

L-5911

YEOMANS

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SPECIALISTS IN SEWAGE LIFT STATIONS—THE COMPLETE LINE

specialists

★ Sewer and Pipe Cleaning Equipment

★ Sewer Rods ★ Sectional Steel Rods

★ Complete Sewer Cleaning Machines

★ Braces and Guides

★ Buckets, Root Cutters, Drag Tools

Save the cost of experimenting. Consult Stewart for any problem in the specialized field of pipe cleaning.

W.H. STEWART, INC. P.O. Box 767, Syracuse, N.Y.

WEMCO®

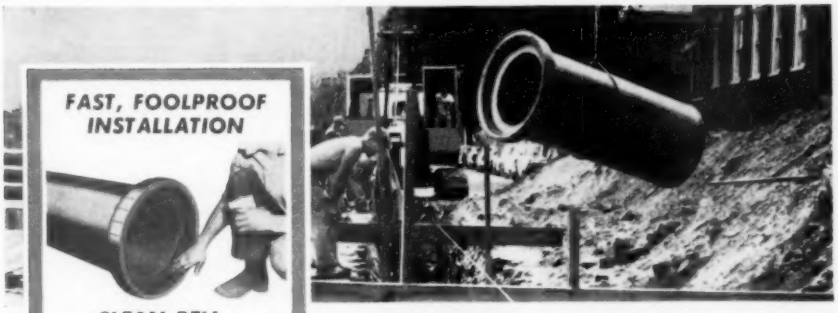
the INCREDIBLE Torque-Flow pump

PUMPED!

Imagine *any* pump passing this bulky object (once an automobile muffler.) Yet the Torque-Flow Pump did it! Hard-to-pump materials that would stop any other pump are handled with ease. What will go in—will come out. Give your pumping problem to the men of Wemco!

reason: recessed impeller; continuous open passage *(what will go in will come out)*

WEMCO® *a division of* Western Machinery Company 650 Fifth St., San Francisco, Calif.



FAST, FOOLPROOF INSTALLATION

CLEAN BELL

CLEAN SPIGOT

PLACE RUBBER "O" RING IN SPIGOT GROOVE

LINE UP, SHOVE INTO PLACE THAT'S ALL THERE IS TO IT!

TODAY'S

FAST, TIGHT, TOUGH FACTORY-MADE JOINT

Wedge-Lock* Type "O"

BY ROBINSON

Now Available In Diameters Through 36"

Now, lines go in faster, seal tighter, stay trouble-free longer. Robinson Type "O" joints reduce laying time . . . cut installation costs . . . are ideally suited to difficult installation conditions. New precision-tight Factory-Made Wedge-Lock Type "O" joints handle infiltration and roots in any terrain.

THE ROBINSON CLAY PRODUCT CO.
ESTABLISHED 1856
AKRON 9, OHIO

*Patented. T.M. Reg. U.S. Pat. Off.

FASTER SERVICE

You get quick delivery of all sizes from strategically located Robinson branches.

FOR MORE DETAILS

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YONKERS, Westchester County, N. Y.
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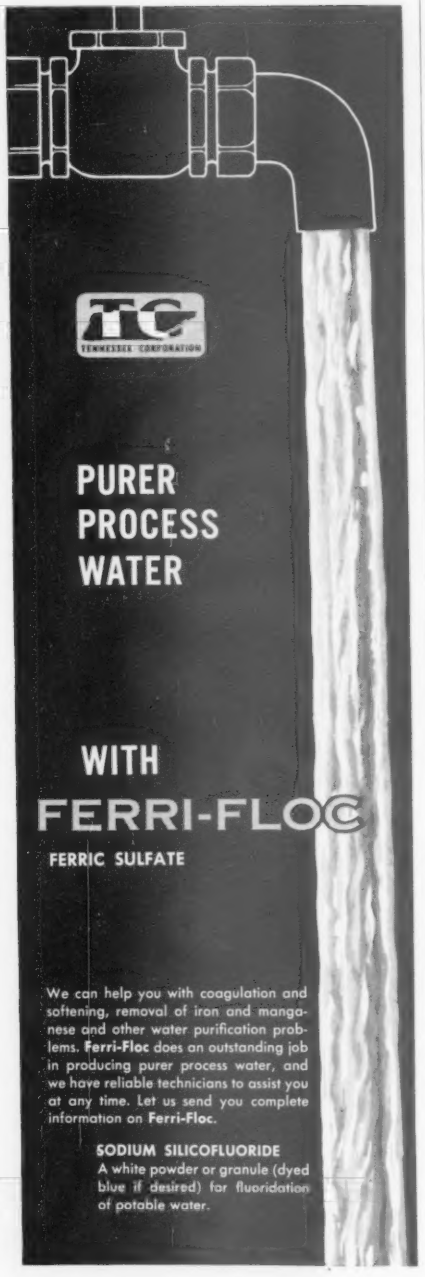
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WITH
FERRI-FLOC
FERRIC SULFATE
We can help you with coagulation and softening, removal of iron and manganese and other water purification problems. Ferri-Floc does an outstanding job in producing purer process water, and we have reliable technicians to assist you at any time. Let us send you complete information on Ferri-Floc.
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A white powder or granule (dyed blue if desired) for fluoridation of potable water.
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members discussing the following topics: "Advance Planning in Memphis," by Justin J. Davis, director, Water Division, Memphis Light, Gas and Water Division, Memphis, Tenn.; "Consultant's Viewpoint," by G. R. Watkins, partner, J. Stephen Watkins Consulting Engineers, Lexington, Ky.; "Murfreesboro Experience," by E. L. Johnson, superintendent, Water Treatment, Murfreesboro, Tenn.; and "Problems General to Annexation" by Victor C. Hobday, executive director, Municipal Technical Advisory Service, University of Tennessee, Knoxville, Tenn.

"Stream Pollution Control—Progress Report of Activities of Tennessee State Government," by Harold V. Miller, executive director, Tennessee State Planning Commission and Member, Tennessee Stream Pollution Control Board, Nashville, Tenn.

"Controlled Discharge of Paper Mill Wastes," by S. J. Sullivan, Jr., chemist, Bowaters Southern Paper Corporation, Calhoun, Tenn.

"Digestion of Domestic and Industrial Waste Solids," by Thomas R. Tucker, sales engineer, Dorr-Oliver Inc., Atlanta, Ga.

"Ft. Loudoun Reservoir Stream Investigation," by Wm. Harold Martin, assistant director, Stream Pollution Control, Tennessee Stream Pollution Control Board, Nashville, Tenn. "Discussion," by Harold L. Elmore, Public Health Engineer, Stream Pollution Control Section, Tennessee Valley Authority, Chattanooga, Tenn.

"Financing Sewerage Improvements," by Linzy D. Albert, Head, State Planning Office, Tenn. State Planning Commission, Nashville, Tenn. "Discussion," by Thomas Mitchell, Cumberland Securities Corp., Nashville, Tenn.

"Industrial Wastes in City Sewers," by Dean M. Taylor, Sanitary Engineer Consultant, Louisville-Jefferson County Metropolitan Sewer District, Louisville, Ky. "Discussion," by

(*Continued on page 152a*)

here's what "out of sight out of mind" does to a water main

"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, *call National now!*

Call in National today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

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Your Member Association Secretary, listed on the third left-hand page of the JOURNAL, or the Federation office, will be glad to send an application form and supply any additional information.

Lasting Service with

DAVCO FLOODED SUCTION SEWAGE LIFT STATIONS

- **Flexible Bulkhead Seals**
- **Flood Control Devices**
- **Trouble-Free Control System**
- **Lifelong Exterior Protection**
  Superior coating with Gunite optional

The Davco Flooded Suction Sewage Lift Stations, the result of years of research and exhaustive tests, provide the most versatile and trouble-free packages available.

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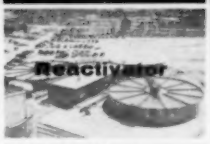
a guide to selecting

WASTE TREATMENT EQUIPMENT

	METAL FINISHING WASTES	WHITE WATER	OILY WASTES
MAXIMUM SOLIDS REMOVAL	Reactivator*	 Reactivator	Reactivator
MINIMUM SPACE REQUIRED	Reactivator	Clariflotor*	Clariflotor
LEAST COSTS	Rota-Rake*	Rota-Rake	Clariflotor
RECOVERY	Ion Exchanger	Reactivator	Clariflotor

*Reactivator®—high-rate solids-contact clarifier and softener *Clariflotor®—flotation unit *Rota-Rake®—horizontal flow gravity clarifier

This chart illustrates the range of equipment Graver offers to meet waste treatment requirements. For example, it shows that when water recovery is desired in white water treatment, the Reactivator is most often the unit to use... and when lowest cost treatment is desired simply to render white water suitable for discharge, the Rota-Rake Clarifier will probably be the unit of choice. When other wastes and other requirements are being considered (see chart) the Clariflotor or Graver Ion Exchangers may be the answer.

There are many factors in making the final choice of process and equipment but, whatever your requirements, Graver can meet them with the widest, finest selection of industrial waste treatment equipment available. And Graver can give maximum service to consultants and plant engineers if contacted during the early stages of planning a waste treatment facility.

Industrial Waste Treatment Department: W-530

Write for General Bulletin 5101
Specific Equipment Bulletins

GRAVER

Graver Water Conditioning Co.
Division of Union Tank Car Company
216 West 14th Street, New York 11, N.Y.

THE BIOLOGY OF Polluted Waters

by H. B. N. HYNES

Written by an authority, this book presents the *biological* aspects of the problem simply and comprehensively. It contains a general outline of freshwater biology and the chemical and physical effects of various types of effluent. Later chapters deal with the biological consequences of each type of pollution and the effect of these on water supplies and amenities. Its photographs, illustrations and extensive international bibliography make it a handbook of immense value to all concerned professionally with this problem.

216 pp. Fully illustrated Postpaid $4.00

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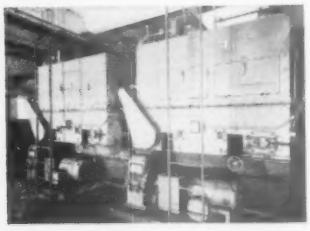
Liverpool 7 England

Manufacturers Since 1885

Gruendler Sewage Shredders everywhere have solved the difficult problem of sewage disposal, helping in the work of SANITATION to prolong the life span of our citizens.



View of TWO Gruendler Sewage Shredders installed in connection with Bar Screens in the Coney Island Treatment Plant. Two other Gruendler Sewage Shredders in Brooklyn, N.Y., have been in operation for 11 years.

See the performance of a Gruendler Shredder, the most modern method of sewage screening, in a city near you. (Locations mailed to you on request)

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2915 N. Market St., St. Louis 6, Mo.

Julian R. Fleming, Director, Division of Sanitary Engineering, Tenn. Department of Public Health, Nashville, Tenn.

"Combined Waste Force Mains," by Frank Kubas, Plant Analyst, Harriman, Tennessee.

"Blasting Claims — Investigations and Evaluations," by Ben L. Greene, Director of Public Relations, Lambert Bros. Div., Special Claims Investigator, Vulcan Materials Company, Knoxville, Tenn.

"Machine Billing and Customer Accounting," by C. F. Wahli, Head of Customers Accounting Section, Knoxville Utilities Board, Knoxville, Tenn.

At the Annual Awards Banquet, C. M. Fair, Vice-Chairman of the Association and Chairman of the Local Awards Committee presented certificates of award to: Raytheon Corporation, Bristol, Tenn.; Bush Brothers & Company, Dandrige, Tenn.; Russell Fork Coal Company, Elkhorn City, Ky.; Metal & Thermit Corporation, Carrolton, Ky.; city of Rockwood, Tenn.; city of Dickson, Tenn.; city of Moorehead, Ky.; and city of Jeffersontown, Ky.

Officers elected for 1961 are:

Chairman: C. M. Fair, Louisville, Ky.
Vice-Chairman: Jack A. Henshaw, Nashville, Tenn.
Secretary-Treasurer: S. Leary Jones, Nashville, Tenn.
Director: Herman D. Regan, Lexington, Ky.

S. Leary Jones
Secretary-Treasurer

Personnel Service

Classified ads will be accepted for "Personnel Available" and "Personnel Wanted" only. Rates are $1.50 per line, with minimum of $5.00. Deadline for ad copy: 10th of the month preceding the issue desired. Send ad copy to Classified Dept., Water Pollution Control Federation, 4435 Wisconsin Ave., Washington 16, D. C. Send replies to same address.

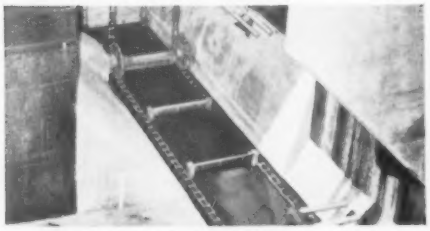
WHICH GRIT COLLECTOR *will protect your system best?*

LINK-BELT builds 7 types, can recommend the most efficient for your needs

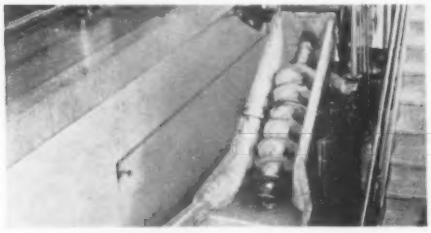
Modern sewage treatment requires grit removal to reduce maintenance costs on mechanical equipment and eliminate operational difficulties. Link-Belt has been manufacturing the finest in grit collection equipment for over 25 years—offers types and designs for any local conditions or requirements. For full details, contact your nearest Link-Belt office. Or write for your copy of Grit Collecting and Grit Washing Book 2571.

LINK-BELT

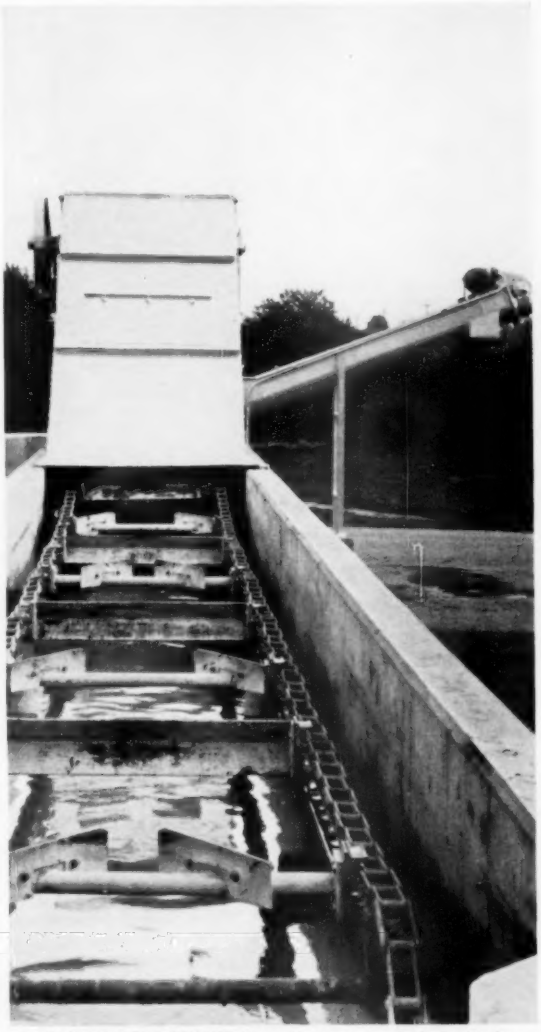
SANITARY ENGINEERING EQUIPMENT



TYPE AB AERATED GRIT COLLECTORS are ideal for large installations, or at plants where it is desirable to combine pre-aeration and grit removal in the same tank. They consist of a Type B grit collector and porous tubes for admitting compressed air.



TYPE SW GRIT WASHER is a separate screw that washes and dewaters grit conveyed to it by pump, ejector, air lift or mechanical means. It can be counted on for long, dependable service in separating grit, water and putrescible matter.



STRAIGHTLINE GRIT COLLECTORS provide an easy method of collecting settled grit and inert solids without draining the grit chamber. These solids are dewatered and removed from the chamber by flight conveyors, screw conveyors, or buckets attached directly to the collectors. Shown is a Link-Belt Type B double-strand installation.

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. Sanitary Engineering Regional Offices—Colmar, Pa., Chicago 9, Kansas City 8, Mo., San Francisco 24. Sales Offices in All Principal Cities. Export Office, New York 7. Representatives Throughout the World. 15,009

WATER POLLUTION CONTROL PRODUCT GUIDE

This list of products and services is offered as an information aid. The list was derived by solicitation from those firms listed. The JOURNAL will make every effort to keep this list current with the help of Associate Members and advertisers. All Associate Members and all advertisers for the past year are included. Many of the services and products are advertised in this issue. For an alphabetical listing see Index to Advertisers in back of JOURNAL.

Aerators (*also see* Diffusers, Air)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Penberthy Mfg. Co., Div. of Buffalo-Eclipse Corp.
Permutit Co., Div. of Pfaudler Permutit Inc.
Smith & Loveless
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Yeomans Brothers Co.
Zimmer & Francescon

Agitators
Link-Belt Co.

Air Cleaning Equipment
Westinghouse Electric Corp.

Air Compressors (*also see* Blowers, Compressors, and Fans)
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Worthington Corp.
Yeomans Brothers Co.

Air Diffusers (*see* Diffusers, Air)

Asbestos Cement Pipe Products
Filtration Equipment Corp.
Industrial Materials Co.
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Ash Handling Equipment
Link-Belt Co.

Bearings
Link-Belt Co.

Bins, Storage (*see* Tanks)

Biologists (*see* Professional Services, elsewhere in this issue)

Blowers (*also see* Air Compressors, Compressors, and Fans)
Chicago Pump Co.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.
Yeomans Brothers Co.
Zimmer & Francescon

Boilers
Combustion Engineering, Inc.

Building Maintenance Equipment and Supplies
Homestead Valve Mfg. Co.

Cast Iron Pipe Products
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Industrial Materials Co.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Cement (*see* Concrete)

Centrifuging Equipment
Bird Machine Co.
Permutit Co., Div. of Pfaudler Permutit Inc.

Chains
Chain Belt Co.
Link-Belt Co.
Webster Mfg., Inc.

Chemical Feed Equipment
Builders-Providence Div., B-I-F Industries
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Fischer & Porter Co.
Graver Water Conditioning Co.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Omega Div., B-I-F Industries
Permutit Co., Div. of Pfaudler Permutit Inc.
Proportioneers Div., B-I-F Industries
Wallace & Tiernan Inc.

Chemicals
Dow Chemical Co.
Fisher Scientific Co.
General Chemical Div., Allied Chemical Corp.
Glenn Chemical Co.
Hach Co.
Tennessee Corp.

Chemists (*see* Professional Services, elsewhere in this issue)

Chlorination Equipment
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Everson Mfg. Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Wallace & Tiernan Inc.
Zimmer & Francescon

Clarifier Equipment (*also see* Sedimentation Equipment)
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Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
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Jeffrey Mfg. Co.
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Lakeside Engineering Corp.
Link-Belt Co.
Permutit Co., Div. of Pfaudler Permutit Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

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National Clay Pipe Mfrs., Inc.
National Sewer Pipe Ltd. (Canada)
Robinson Clay Product Co.

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Inertol Co., Inc.
Koppers Co., Inc.
National Water Main Cleaning Co.
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Smith & Loveless
Walker Process Equipment Inc.
Worthington Corp.

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Roots-Connersville Blower, Div. of Dresser Industries Inc.
Worthington Corp.
Yeomans Brothers Co.

Computers
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.

Concentrators (*see* Sludge Concentrators)

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Portland Cement Assn.

Concrete Pipe Products
American Concrete Pressure Pipe Assn.
American-Marietta Co.
Gray Concrete Pipe Co., Inc.
Industrial Materials Co.
Lock Joint Pipe Co.
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Eimco Corp.
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In a Worthington comminutor, all teeth are mounted as units called "cutter bars." This makes servicing much faster and doubles tooth life. Here's why . . .

As you can see for the 7" comminutor above, there are just one stationary and four rotating bars. Thus all teeth are removed by releasing just five cutter bars, instead of many teeth one by one. There is far less cutter adjustment, too. Note also that the 7" comminutor rotating cutter bars are reversible. Thus you get double the cutter life until resharpening. And resharpening is faster, too, because cutter bars are much easier to handle than separate teeth.

And here are three other exclusive Worthington 7" comminutor features (compare them); 33% more power through using a ⅓ hp motor; greater capacity . . . up to .45 mgd; and easier installation with flanged or bell and spiggot construction.

Worthington's 7" comminutor is ideal for packaged treatment plants and unattended stations. Larger Worthington comminutors with equally desirable advantages handle flows up to 26 mgd. For more information, write Worthington Corporation, Department 105-7, Harrison, N. J. In Canada, Worthington (Canada) Ltd., Brantford, Ontario.

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Homestead Valve & Meter Co.
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Westinghouse Electric Corp.
Worthington Corp.

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Stuart Corp.
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Chicago Pump Co.
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Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
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Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Zimmer & Francescon

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Walker Process Equipment Inc.
Yeomans Brothers Co.

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Hardinge Co., Inc.
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Link-Belt Co.
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Smith & Loveless
Vapor Recovery Systems Co.
Walker Process Equipment Inc.
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Zimmer & Francescon

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Dorr-Oliver Inc.
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Infilco Inc.
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Pacific Flush Tank Co.
Smith & Loveless
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Dryers
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Combustion Engineering, Inc.
Eimco Corp.
Hardinge Co., Inc.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Nichols Engr. & Research Corp.
Stuart Corp.

Ejectors
Komline-Sanderson Engr. Corp.
Smith & Loveless
Tex-Vit Mfg. Co.
Yeomans Brothers Co.

Engineers (*see* Professional Services, elsewhere in this issue)

Engines (Sludge Gas and Petroleum Fuels)
Fairbanks, Morse & Co.
Waukesha Motor Co.
Worthington Corp.

Fans (*also see* Air Compressors, Blowers, and Compressors)
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Lakeside Engineering Corp.
Westinghouse Electric Corp.

Filter Equipment, Trickling
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Ralph B. Carter Co.
Dorr-Oliver Inc.
Dow Chemical Co.
Eimco Corp.
Filtration Equipment Corp.
Industrial Materials Co.
Infilco Inc.
Keasbey & Mattison Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Nichols Engr. & Research Corp.
Pacific Flush Tank Co.
Smith & Loveless
Trickling Filter Floor Inst.
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Filtration Equipment Corp.
Glenn Chemical Co.
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Industrial Materials Co.
Johns-Manville Sales Corp.

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Graver Water Conditioning Co.
Yeomans Brothers Co.

Filters, Vacuum (*also see* Vacuum Filters)
Bird Machine Co.
Dorr-Oliver Inc.
Eimco Corp.
Proportioneers Div., B-I-F Industries

Flocculating Equipment
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American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
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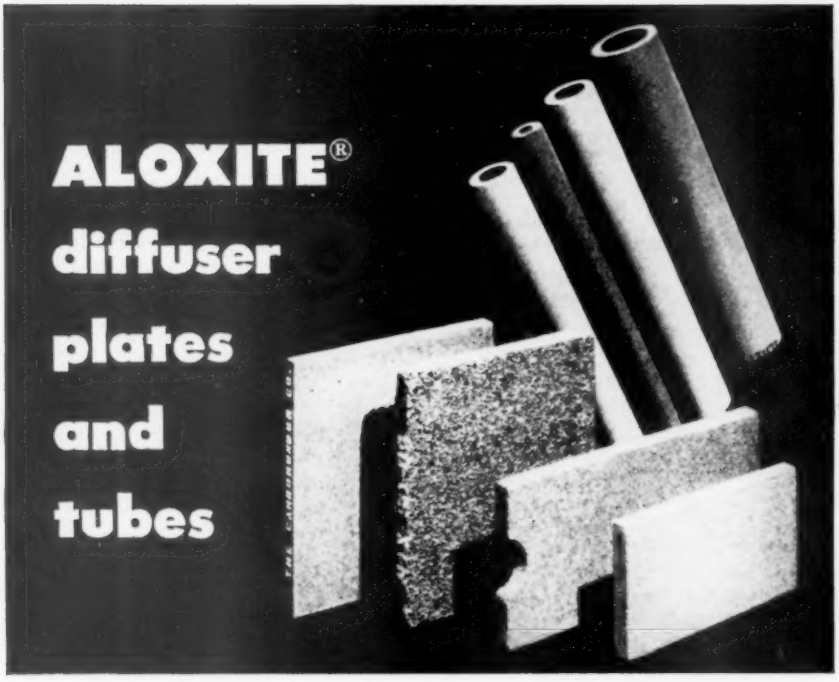

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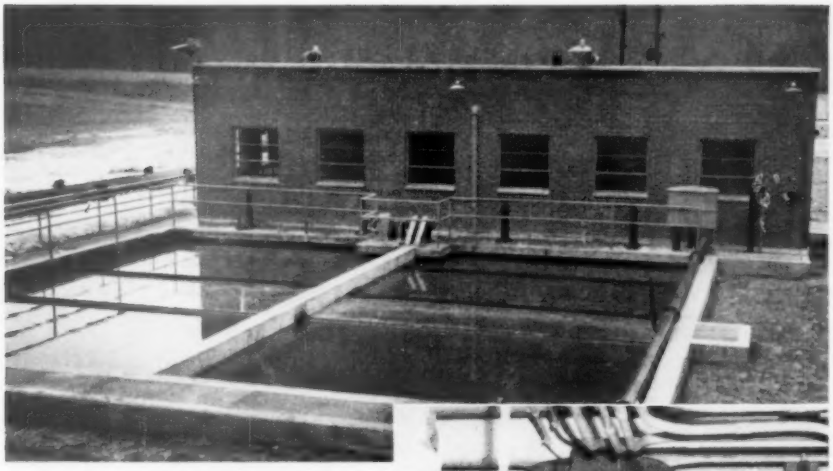

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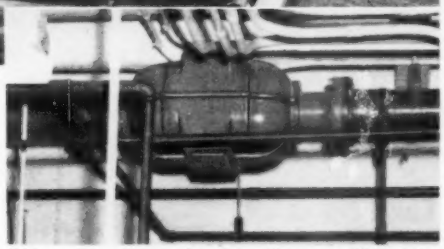

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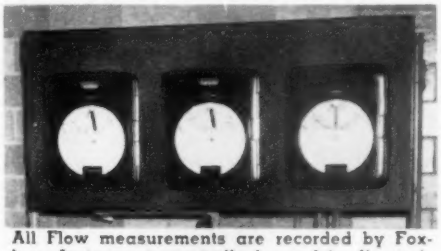

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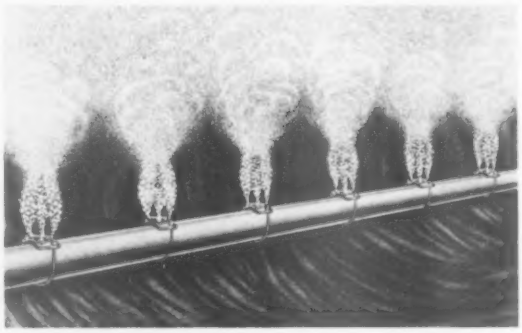

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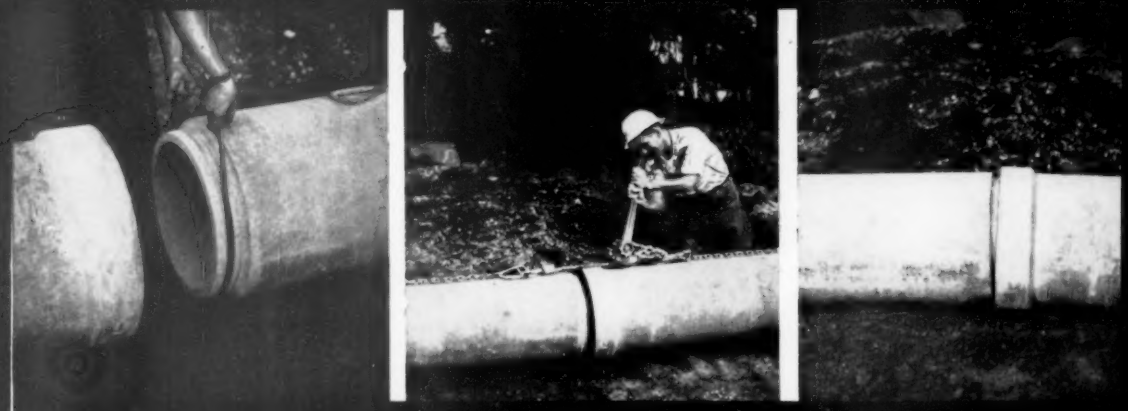

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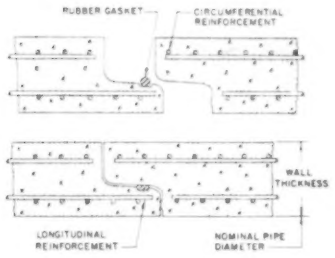
LOCK JOINT

RUBBER and CONCRETE JOINT



SEWER AND CULVERT PIPE PLANTS:

Kenilworth, N. J.	Beloit, Wis.	Denver, Colo.
Hartford, Conn.	Chicago, Ill.	Cheyenne, Wyo.
New Haven, Conn.	Rock Island, Ill.	Casper, Wyo.
Buffalo, N. Y.	Valley Park, Mo.	Tucumcari, N. Mex.
Rochester, N. Y.	N. Kansas City, Kans.	Hato Rey, Puerto Rico
Edgewater, Fla.	Tulsa, Okla.	Carolina, Puerto Rico
Miami, Fla.	Oklahoma City, Okla.	Ponce, Puerta Rico
W. Palm Beach, Fla.	Wichita, Kans.	Caracas, Venezuela

Long life is built into every section of Lock Joint Roller Suspension Sewer and Culvert Pipe through a manufacturing process which produces concrete walls of unusual strength and density.

The non-corrosive, non-tuberculant inner surface of the pipe is remarkably resistant to abrasion and assures continued high flow characteristics and trouble-free service.

Lock Joint's Rubber and Concrete Joint, available in this type of pipe and in some designs of conventionally cast pipe, gives maximum protection against infiltration while affording ample flexibility to accommodate deflections due to ground settlement and expansion of contraction due to temperature changes.

For economy in jointing, Roller Suspension Pipe is produced in standard 8′ lengths and is available in diameters from 12″ to 72″. Lock Joint Pipe Company also produces machine made and cast pipe ranging in diameter from 6″ to 120″ or even larger if required. All Lock Joint sewer and culvert pipe may be designed to comply with A.S.T.M., State Highway or individual specifications.

LOCK JOINT PIPE CO.

East Orange, New Jersey

Pressure • Water • Sewer • **REINFORCED CONCRETE PIPE** • Culvert • Subaqueous

W&T **COMPOUND-LOOP CONTROL**

With automation by Wallace & Tiernan your chlorination system controls itself . . . needs almost no attention. With Compound-loop Control, the residual you select is maintained, no matter how much water flow or chlorine demand changes. You're always sure of water quality.

W&T Compound-loop Control means true process control. Because it analyzes the end result and feeds back information which monitors your chlorinator, Compound-loop Control successfully achieves a closed-loop system. This means an operating range of greater than 100 to 1, plus round-the-clock supervision without extra labor.

And you can control free or total residual . . . use electric, pneumatic, or variable vacuum signals. W&T Compound-loop Control can be tailored to the physical layout of your system, your flow-metering equipment, your plant hydraulics. You build or convert to automation with maximum convenience, minimum expense.

For more information, write Dept. S-141.84

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